# An Information Model of the Construction Cost Estimating Process

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## ACKNOWLEDGEMENTS

Over the years in which this work was prepared many persons have suffered the consequences of my involvement with it, my colleagues, my friends and not least my family. I apologise to them all. I also thank Frances, Joseph and Diane for their support and John for his understanding.

## ABSTRACT

It is argued that a fundamental criterion which has received little consideration in the investigation of cost prediction is the impact of information upon accuracy. An information model is developed by drawing on the work of communication engineers, information scientists and psychologists. It is then demonstrated that information cannot be divorced from the knowledge of the receiver and as such it then becomes necessary to determine how knowledge is accumulated and how this then impacts upon the need and demand for information, the choice of relevant information, as well as how that information is utilised. The concept of relevance is considered from a logical and psychological perspective. On completion of this analysis the information model which links cost estimating with entropy, information and knowledge is completed. It is argued that the developed model is comprehensive and facilitates the progression of research in this field. The model is then used as a basis for the investigation of the relationship between information and expertise in estimating, choice of information for estimating, impact of information on estimating, perceptions of information quality and the perceptions of the importance of information facets and attributes to the estimating process.

## STRUCTURE OF THESIS

This thesis commences in the Prolegomena with a review of the hypothetico-deductive approach to research and compares this to that propounded as the change of paradigm approach. While it is noted that there is much in common it is argued that the approach to be adopted in this work should be more reflective of the latter approach. This approach is confirmed in Chapter 1 as a consequence of the review of previous research and literature relating to the accuracy of cost prediction of building work by both the design team and the contractor. This chapter draws heavily on the work of Skitmore (1981, 1985, 1986, 1987), Ashworth (1982), Morrison and Stevens (1981), Ogunlana (1987, 1989) and other United Kingdom based researchers as well as investigators from the United States of America and other countries.

It is argued from this historical base that a fundamental criterion which has received little or no consideration in the investigation of cost prediction is the impact of information upon accuracy. Where the concept of information is alluded to it is seen to be in a superficial and non scientific way with no attempt made at rigorous definition. It is argued that this situation has arisen as a consequence of the predominance of cost and resource based paradigms to the exclusion of an information/communication based paradigm. The development of such a paradigm and the associated model is perceived as an essential pre-cursor to the investigation of the impact of information upon the accuracy of cost prediction systems.

In Chapter 2 design is shown to be an entropic process in which information is essential to ensure that the initial concept is transformed into form with minimum 'chaos' and maximum understanding. The problems of the communication of information in the technical domain are then identified by drawing on the work of communication engineers and information scientists. Using this base a technical model, (being essentially a communication engineers model) is developed as a preliminary move toward a more comprehensive model in which logical and psychological views are included. Using this approach it is possible to identify the significant features which would impact upon the quality of information, were one in a position to define that which constitutes information in the context of cost estimating. These features are noise, redundancy, context and signification.

It is argued in Chapter 3 that the major instrument for the communication of information upon cost is the bill of quantities and that in the development of a model of the information system one has to identify those attributes which configure the system. The views of 'experts' are taken and compared. Differences are identified as are the dangers of construing from these views that information attributes necessarily identify significant information.

In Chapter 4 it is demonstrated that 'the map is not the territory' and that there are dangers in assuming that information demands and information wants are the same thing. It is at this stage that it is necessary to arrive at a firm definition of information. Information is shown to be an extremely complex phenomenon which has attracted various interpretations and definitions. After a comprehensive review, of these conclusions are reached and a definition arrived at which is consistent for the developing model.

The previously developed preliminary technical model is now further developed as a consequence of the consideration of concepts of, grade of organisation, pragmatic/semantic informativeness, process and product, rational and intuitive knowledge and bound information.

It is demonstrated in Chapter 5 that information cannot be divorced from the knowledge of the receiver and as such it then becomes necessary to determine how knowledge is accumulated and how this then impacts upon the need and demand for information, the choice of relevant information, as well as how that information is utilised. This therefore develops the loosely defined term 'experience' as found in the work of previous researchers.

The concept of relevance is extremely complex and in order to fully define it within the context of cost estimating it is essential to consider it from a logical and psychological perspective. This is done in Chapter 6 and on completion of analysis of the concept of relevance it is then possible to complete the information model which links cost estimating with entropy, information and knowledge. The developed model is seen to be comprehensive and extremely complex. Such comprehensiveness facilitates the logical progression of research in this field but the associated complexity requires that such research can only progress by attacking discrete parts of the model which can then be integrated into the model when fully understood.

In Chapter 7 the discrete areas identified in the model for investigation are brought together in summary to provide a succinct review of the thesis and so to provide a guide for initial investigations and further work. An nitial investigation which has been carried out is described in the appendices. This chapter also reviews the results of the investigation and notes the conditions under which the investigation took place. The conclusions are placed within the context of the overall model and areas for further investigation identified.

Appendix A identifies the area for investigation. This is the perception of Quantity Surveyors and Estimators of the information which is important to the estimating process. Methodological arguments are reviewed form previous research into relevance and a methodology prepared. The techniques of questionnaire, interview and model tasks are utilised with samples of practising quantity surveyors, contractors estimators, undergraduate quantity surveyors and post graduate students.

Appendix B details the investigations which took place into the relationship between information and expertise in estimating, choice of information for estimating, impact of information on estimating, perceptions of information quality in the bill of quantities and the perceptions of the importance of information facets and attributes to the estimating process,

# PROLEGOMENA

# METHODOLOGICAL APPROACH

## P.1 Hypothetico-Deductive Model

The most fully reasoned exposition of the hypothetico-deductive model is that of Popper (1959). However, much of the concept had previously been propounded by Whewell in 1840;

"A facility in devising hypotheses, therefore, is so far from being a fault in the intellectual character of a discoverer, that it is in truth, a faculty indispensable to his task. To form hypotheses, and to employ much labour and skill in refuting, if they do not succeed in establishing them, is a part of the usual process of inventive minds. Such a proceeding belongs to the rule of the genius of discovery, rather than (as I have often been taught in modern times) the exception" and "Since the discoverer has thus constantly to work his way onwards by means of hypotheses, false and true, it is highly important for him to possess talents and means for rapidly <u>testing</u> each supposition as it offers itself. The hypotheses which we accept ought to explain phenomena which we have observed. But they ought to do more than this: our hypotheses ought to foretell phenomena which have not yet been observed (but which are) of the same kind as those which the hypothesis was intended to explain".

This is developed by Popper (1959); "A scientist, whether theorist or experimenter, puts forward statements or systems of statements, and tests them step by step. In the field of the empirical sciences, more particularly he constructs hypotheses, or systems of theories and tests them against experience by observation and experiment."

This approach can therefore be put in terms of "conventions" or "rules" governing the game of science.

Lakatos (1974) explains this as such; "The opening move must be a consistent, falsifiable hypothesis; that is a consistent hypothesis which has agreed on potential falsifiers. A potential falsifier is a basic statement whose truth value is decidable with the help of the experimental techniques of the time. The scientific jury must agree unaminously that there is an experimental technique which will enable them to assign a truth value to the basic statement". and "The next move is the repeated performance of the test in a controlled experiment and the second decision of the jury on what actual truth value (truth or falsehood) to attribute to the potential falsifier. If the second verdict is negative, and the potential falsifier is rejected, then the hypothesis is declared corroborated, which only means that it invites further challenges. If the second verdict is positive then the hypothesis is buried with military honours. After the burial a new hypothesis is invited.

This new hypothesis must however explain the partial success if any of its predecessor, and also something more".

The argument is thus that if the scientific game is played correctly, science will progress as the theories subsequently proposed will have increasing generality (or emprical content) and they will "pose ever deeper questions about the universe" Lakatos (1974)

## P.2 Scientific Revolutions

Kuhn (1974) argues that the Popper approach encapsulated in the above does not suggest that "science progresses by accretion" and proposes that both he and Popper (1959) "emphasise instead the revolutionary process by which an older theory is rejected and replaced by an incompatible new one; and both deeply underscore the role played by the older theory's occasional failure to meet challenges posed by logic, experiment or observation". Kuhn (1974), further notes "we both insist that scientists may properly aim to invent theories that explain observed phenomena and that do so in terms of real objects".

It would seem therefore that the distinction between the approaches of Kuhn and Popper is in how one arrives at the important stage of 'theory invention'.

According to Popper, every theory is all the time being tested, no matter what applications are going on. Thus the daily work of science, if not revolutionary, aims at small scale rebellion (which might blossom into a revolution at any moment). According to Kuhn (1962), the situation is quite different: one is not attempting to test a theory at all; in certain circumstances one is concerned simply to exploit it, use it, extend it, apply it. "Kuhn sees normal science as neither an activity of trying to falsify one's paradigm nor as an activity of trying to confirm it, but as something else", (Wisdom 1974).

Kuhn (1974) does accept however that "There is one sort of "statement" or "hypothesis" that scientists do repeatedly subject to systematic test. I have in mind statements of an individual's best guesses about the proper way to connect his own research problem with the corpus of accepted scientific knowledge. ... In each case the next steps in his research are intended to try out or test the conjecture or hypothesis. If it passes enough or stringent enough tests, the scientist has made a discovery or at least has resolved the puzzle he had been set", and, "Many research problems, though by no means all, take this form. Tests of this sort are a standard component of what I have elsewhere labelled normal science or normal research"

Popper's theory of refutability is that for a theory to be accredited as scientific it has to be refutable, and one has to be able to specify what would constitute a refutation. This means that if a consequence of a theory turns out to be wrong, then the theory is falsified.

When valid attempts at puzzle solving have failed, then one has what Kuhn calls an 'anomaly'. When an anomaly occurs a number of times, then one has a situation that Kuhn describes as a crisis. That is to say a number of anomalies turn up, puzzles, which cannot be explained away or explained within the terms of the theory.

It is at this point that it becomes reasonable for scientists to consider that perhaps, after all, the fault lies not with the initial conditions but with the fundamental theory. Further, Kuhn (1974) argues that in the hypothetico-deductive model propounded by Popper (1959), "In no usual sense, however, are such tests directed to current theory. On the contrary, when engaged with a normal research problem, the scientist must premise current theory as the rules of his game. His object is to solve a puzzle, preferably one at which others have failed, and current theory is required to define that puzzle and to guarantee that, given sufficient brilliance, it can be solved".

Wisdom (1974) notes that for Kuhn there is an extralogical factor in the situation: the scientist does not wish to give up the theory when an anomaly first arises. ... "The new theory cannot be adopted on any kind of logical grounds, for it creates too many new problems and there is no knowing whether they will be too difficult for it, and it is adopted at least partly because it gets over the immediate crisis" (Kuhn 1962). Popper's theory, by contrast, appears to depend entirely on logical considerations.

### P.3 The Paradigmatic Model

The heart of Kuhn's account is the notion of a paradigm. On this explanation, a paradigm is simply a scientific theory together with an example of a successful and striking application. "It is important that the application ... be striking ..." (Putnamm 1974).

Once a paradigm has been set up and a scientific field has grown up around that paradigm, we get an interval of what Kuhn calls "normal science". The activity of scientists during such an interval is described by Kuhn as "puzzle solving".

What finally terminates the interval is the introduction of a new paradigm which manages to supersede the old.

Butterfield (1947) suggests that, so far from 'revolutions' being traceable to external factors, the position is that scientists are at some stage floundering with problems, in struggling with which they undergo a change in the workings of their minds, they see old things in a new way, and manage to get a key idea, then with key the lock is turned, so to speak. Second, when unlocked, the sluice gates are opened. By which he means the discoveries then flow along very easily, once you have got the key and unlocked the gates. It seems that these concepts very much parallel with Kuhn's paradigm, and the sluice gates are Kuhn's 'normal' science consisting of puzzle solving. Thus normal science is seen as non-revolutionary as in some periods the scientist is concerned with elaborating knowledge he already has, i.e. making and getting more accurate estimates of existing knowledge. In addition there are other sorts of activities such as 'articulating' a theory more precisely, (Wisdom 1974), and "You can first of all elaborate the theory in the simple terms in which it was originally given, and then you may decide that it would be interesting to exploit it in certain other fields, such as in other media. ... This gives a vast amount of work of a normal kind which takes a great degree of originality to do and is highly characteristic of ordinary science as it goes along from day to day. But no revolution in theory is involved". (Wisdom 1974).

It is argued that when a difficulty arises, one does not at once go about it by regarding it as a problem and scrapping the fundamental theory; one should first try all the devices of puzzle solving one can think of, to accomplish the initial task. For, "... scientists will be reluctant to embrace a new candidate for paradigm unless convinced that two all important conditions are being met. First the new candidate must seem to resolve some outstanding and generally recognised problem that can be met in no other way. Second, the new paradigm must promise to preserve a relatively large part of the concrete problem solving ability that was accrued to science through its predecessors", (Kuhn 1962).

Kuhn (1962) gives examples of paradigms, such as Newton's theory of gravitation or Einstein's general theory of relativity, meaning that they are <u>dominant</u> theories in terms of which one views all the problems that arise in a certain field. Kuhn also often speaks of a paradigm as if it stood for the <u>empirical content</u> of a dominant scientific theory. For example, the paradigm of Newton's celestial mechanics is the inverse square law of gravitation, the obvious hall mark of empirical content is that it should be empirically testable, i.e. refutable.

However, Kuhn's most controversial assertions have to do with the process whereby a new paradigm supplants an older paradigm. Here he has been accused of being radically subjectivist (Putnam 1974). He argues that data, in the usual sense, cannot establish the superiority of one paradigm over another because data themselves are perceived through the spectacles of one paradigm or another. Changing from one paradigm to another requires a 'Gestalt' switch. The History and methodology of science gets rewritten when there are major paradigm changes;

so there are no "neutral" historical and methodological canons to which to appeal.

Wisdom (1974) develops this argument and suggests that when one has a large scale theory and embedded ontology, one has a special way of looking upon the world. Wisdom (1974) calls this the Weltanschauung of the theory.

The embedded ontology and the Weltanschauung are premissed as conceptually quite distinct in the sense that the embedded ontology is a structure attributed to the world, whereas the Weltanschauung is a way of seeing the world in view of this structure.

Wisdom further argues that one cannot give an adequate account of what happens in the period of scientific revolution in terms of paradigms unless one gives it at least in terms both of the empirical content of a theory and also the embedded ontology.

The phase of elaboration of a theory consists of exploiting the empirical content of a paradigm. Wisdom (1974) argues this is so given the puzzle. But the selection of the puzzle depends upon its being amenable to treatment by the empirical content; and its being amenable to treatment would seem to consist in its conformity to the embedded ontology or to the Weltanschauung of the paradigm. For while in regard to scientific revolution, many scientists argue that in the end what tells is the empirical content of a theory, i.e. what is 'normally' tested is the empirical content, Wisdom (1974) submits "I do not think it is what governs controversy about a change over ... I submit that it is the embedded ontology or Weltanschauung that catches scientists emotions".

Thus as long as the fundamental theory is protected, puzzle solving and paradigm exploitation as defined by Kuhn continue. It is the empirical content of a paradigm which counts in the phase of exploitation of a theory, and the nature of the puzzles selected is determined by their satisfying the embedded ontology or the Weltanschauung of the paradigm. Scientific revolution however, seems to concern primarily the embedded ontology or the Weltanschauung. For one of the factors keeping controversy alive is that questions of ontology and Weltanschauung cannot be settled by observational testing (Wisdom 1974, Kuhn 1962).

Thus, "empirical content determines puzzle solving; the puzzles themselves are selected in accordance with embedded ontology or Weltanschauung. Controversy, or a battle of paradigms, is due to the Weltanschauung centring on the embedded ontologies at issue, and it cannot be settled by observational test; but, in the end, it is specific empirical content evidence, intersubjectively available, that constitutes the rational grounds upon which leading scientists relinquish one paradigm and adopt another; and the new Weltanschauung leads to a bandwagon effect".

## P.4 Testing of Theory

Kuhn (1962) maintains that the paradigm that structures a field is highly immune to falsification in particular, it can only be overthrown by a new paradigm. "What is true, I believe,....is that ... a theory which is paradigmatic is not given up because of observational and experimental results by themselves but only because and when a better theory is available". He also states that "...to say ... that paradigm change cannot be justified by proof, is not to say that no arguments are relevant...". However this must not be interpreted as indicating that a paradigm should be judged solely on comparative ability to solve problems. "To scientists these arguments are primarily the most significant and the most persuasive ... But ... they are neither individually nor collectively compelling" (Putnam 1974).

"... if a new candidate for paradigm had to be judged from the start by hard headed people who examined only relative problem solving ability, the sciences would experience very few major revolutions", (Kuhn 1962).

Putnam (1974) has suggested the following interpretation:

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SCHEMA I
----------
THEORY
AUXILIARY STATEMENTS
--------------------
PREDICTION - TRUE OR FALSE

SCHEMA II
----------
THEORY
??????????
-------------
FACT TO BE EXPLAINED
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It is argued that these are both schemata for scientific problems. In the first type of problem there is theory and some Auxiliary Statements, a prediction is derived and the problem is to see if the prediction is true or false: the situation emphasised by standard philosophy of science. In the second type of problem there is a theory and a fact to be explained, but the Auxiliary Statements are missing: the problem is to find the Auxiliary Statements which are true, or approximately true (i.e. useful oversimplifications of the truth), and which can be conjoined to the theory to get an explanation of the fact. Relating this concept to the work that follows here it can be demonstrated that there is a 'fact' of differential level of estimating accuracy between the design stage and the construction stage. It can also be proposed that this is a function of the information system and that presently the theory which defines this relationship as well as the auxiliary statements have yet to be defined.

"Problems of the SCHEMA II type are sometimes mentioned by philosophers of science when the missing auxiliary statements are laws; but the case..in which the missing auxiliary statement was just a further contingent fact about the particular system is almost never discussed. I want to suggest that the SCHEMA II exhibits the logical form of what Kuhn calls a puzzle", (Putnam 1974).

Putnam (1974) has further noted that in tackling a SCHEMA II - type problem "there is no question of deriving a prediction, ... the whole is to find the Auxiliary Statements. The theory ... is unfalsifiable in the context. It is also not up for "confirmation" any more than for "falsification"; it is not functioning in a hypothetical role. Failures do not falsify a theory, because the failure is not a false prediction from a theory together with known and trusted facts, but a failure to find something - in fact, a failure to find an Auxiliary Statement,". Theories are highly immune to falsification; the period of acceptance is ended by the appearance of a better theory or a whole new explanatory technique. Similarly, "successes do not "confirm" a theory, once it has become paradigmatic, because the theory is not a "hypothesis" in need of confirmation, but the basis of a whole explanatory and predictive technique, and possibly of a technology as well", (Putnam 1974).

The tendency represented by SCHEMA I is the critical tendency the importance of which has been confirmed by Popper. The tendency represented by SCHEMA II is the explanatory tendency.

Putnam (1974) argues that "The solution to a SCHEMA II - type problem must itself be confirmed, frequently by a SCHEMA I - type test. In short, attempted falsifications do "corroborate" theories - not just in Popper's sense, in which this is a tautology, but in the sense he denies, of showing that they are true or partly true - and explanations on the basis of laws which are regarded as known frequently require the introduction of hypotheses. In this way the tension between the attitudes of explanation and criticism drives science to progress".

Kuhn stresses the way in which a scientific theory may be immune from falsification whereas Popper stresses falsifiability as the sine qua non of a scientific theory.

A theory is only accepted if the theory has substantial, non-ad hoc, explanatory successes. This is in accordance with Popper; however it is also in accordance with the "inductivist" accounts that Popper rejects, since these stress <u>support</u> rather than falsification.

"We obtain our ideas - our correct ones, and many of our incorrect ones - by close study of the world. Popper denies that the accumulation of perceptual experience leads to theories: he is right that it does not lead to theories in a mechanical or algorithmic sense; but it does lead to theories in the sense that it is a regularity of methodological significance that (1) lack of experience with phenomena and with previous knowledge about phenomena decreases the probability of correct ideas in a marked fashion; and (2) extensive experience increases the probability of correct or partially correct, ideas in marked fashion. "There is no logic of discovery" - in that sense, there is no logic of "testing" either; all the formal algorithms proposed for testing, by Carnap, by Popper, by Chomsky, etc., are, to speak impolitely, ridiculous... There are maxims for discovery and maxims for testing: the idea that correct ideas come from the sky, while the methods for testing them are highly rigid and predetermined is one of the worst legacies of the Vienna Circle", (Putnam 1974)

But the correctness of an idea is not certified by the fact that it came from close and concrete study of the relevant aspects of the world; in this sense Popper is right. But one judges the correctness of ideas by applying them and seeing if they succeed; in general, and in the long run, correct ideas lead to success and wrong ideas lead to failures where and in so far as they are incorrect.

Popper traces the origin of "the tradition of critical discussion (which) represents the only practicable way of expanding our knowledge" to the Greek philosophers between Thales and Plato. The accompanying description of Presocratic does not resemble science. Rather, it is the tradition of claims, counter claims, and debates over fundamentals which, have characterised philosophy and much of social science ever since. By the Hellenistic period, mathematics, astronomy, statics, and the geometric parts of optics had abandoned this mode of discourse in favour of puzzle solving. "In a sense, to turn Sir Karls view on its head, it is precisely the abandonment of critical discourse that marks the transition to a science. Once a field has made that transition, critical discourse recurs only at moments of crisis when the bases of the field are again in jeopardy. Only when they must choose between competing theories do scientists behave like philosophers. That I think, is why Sir Karl's brilliant description of the reasons for the choice between metaphysical systems so closely resembles my description of the reasons for choosing between scientific theories. In neither choice.... can testing play a quite decisive role" (Putnam 1974).

No puzzle-solving enterprise can exist unless its practitioners share criteria which for that group and for that time, determine when a particular puzzle has been solved.

But under the special circumstances which induce a crisis in the profession (e.g. gross failure, or repeated failure by the most brilliant professional), the group's opinion may change. A failure that had previously been personal may then come to seem the failure of a theory under test. And thereafter because the test arose from a puzzle and thus carried settled criteria of solution, it proves both more severe and harder to evade than the tests available within a tradition whose normal mode is critical discourse rather than puzzle solving.

Of the two criteria, testing and puzzle solving, the latter is at once the less equivocal and the more fundamental.

"Where a theory's failure to provide rules that identify solvable puzzles is viewed as the source of professional crisis which often results in the theory's being replaced", (Kuhn 1962).

It is not proposed that there are rules for inducing correct theories from facts, or that theories, correct or incorrect, are induced at all. Rather, they are "imaginative posits", invented in one piece for application to puzzles. Though such posits can and usually do at last encounter puzzles they cannot solve, these confrontations rarely occur for some time after a theory has been both invented and accepted.

However, the view taken here is that a scientific community will seldom or never embrace a new theory unless it solves all or almost all the quantitative numerical puzzles that have been treated by its predecessor. Unfortunately, tackling "all the quantitative numerical puzzles" is rarely possible in a single work.

## P.5 Cost Estimating

Within the research context of cost estimating the Popper puzzle solving approach has been dominant, with much empirical work being expended to identify levels of estimating accuracy achieved by the design team and by the contractor. This has been done for various types of product, size of project, stages of design process, in different countries and with different levels of expertise. It is argued that this approach has produced much insight into the levels of estimating accuracy achieved within the parameters of the chosen discrete puzzle but have made little or no contribution to the development of a theory (paradigm) which can solve "all the quantitative numerical puzzles". It is precisely the adoption of the Schema I approach to research which constrains the development of a revised theoretical framework and has as a consequence resulted in the requirement for critical discourse, for it is argued, that despite the extensive research work noted above and later, little or no contribution has been made to improving estimating accuracy in the real world (Ogunlana 1989). It is believed that within Kuhn's terms this constitutes a 'crisis' in research, for to continue with the current hypothetico-deductive puzzle solving approach without any significant contribution to the identification of the 'Auxiliary Statements' is simply to pursue research within a vacuum. "The history of science provides a lesson: Experimentation without connection to or from theories eventually becomes circular, stagnant, insignificant and sterile, introvert and always ending with soul splitting orientation toward methodological problems", (Saracevic 1975).

Inevitably, and taking cognizance of the work of Kuhn (1962) and Wisdom (1974) the approach of Popper is not applicable here. For to adopt the hypothetico-deductive model is to accept the current paradigmatic view of research into estimating. The 'crisis' or series of 'anomalies' in estimating are identified in Chapter 1 later but essentially relate to the consequences of a failure to comprehensively identify and relate Auxiliary Statements necessary to create a theory within which further puzzle solving can take place. Only by identifying and relating the Auxiliary Statements can a theory be developed which may then inform the puzzle solving aspects of normal science. A problem remains in that in the creation of a new paradigm which though ultimately 'testable' through the actions of normal science cannot itself be created through normal science. It is proposed that the need for it can be evidenced through the application of normal science to an existing paradigm but the creation of a new paradigm can only result from critical discourse and the possible adoption/modification of a paradigm from an alternative discipline. This approach is adopted here.

# CHAPTER 1

# CONTEXT

## 1.1 Predicting the Future

The context of this research is cost 'estimating'. As a concept estimating has been likened to an art (Shaw 1975), an attempt to predict (Harrison 1981), an attempt to control (Rolf 1972), 'witchcraft' and 'guessing' (Fine 1974). A reasonable starting point for the consideration of estimating is provided by the definition supplied by Ashworth and Skitmore (1982), i.e. "an estimate is a reasonably accurate calculation and assessment of the probable cost of carrying out defined work under known conditions ". A review of this definition indicates that the estimator will have no problems in his estimate if the work is well defined and the future is known.

$$E_{acc} = f(I + F) \tag{1}$$

Where $E_{acc}$ is estimating accuracy.
I is information.
F is the future.

Any investigation of a process which attempts to predict the future must necessarily consider a number of philosophical questions. In doing this we can turn to the work of Shackle (1955). In regard to the future, Shackle suggests three possible conditions of knowledge. The first of these is based upon the concept of a deterministic world which cannot be influenced by the application of free will and choice. The second assumes that it is possible to have perfect knowledge. Thus it would be possible to investigate all possible outcomes and identify the optimum solution. The third condition accepts an absence of order and presumes that the world is inherently unpredictable.

Though providing a useful base from which to consider influences upon predictability the above views of knowledge remain essentially simplistic. For while it may be argued that the Newtonian view of a deterministic world founded on the Cartesian philosophical basis of a fundamental division between 'I and the world' has proven its worth in the rapid development of science, it is also true that in developing the Theory of Relativity, Einstein removed for ever the notion that it is possible to separate the actor from the event and produce totally objective assessments and predictions.

As it is impossible to have perfect knowledge, the problem of predictability of the future reduces to the analysis of free will in those areas over which man has some influence. Hence, it can be assumed that people retain a free will but many of these actions can be predicted. This is because free will is a relative concept and exists only in reference to a datum, i.e. the individuals idea about his own freedom. Free will therefore exists, but does not imply that an individual can do anything possible, for an individual's choice of action will be determined and be in conformity with his values, which it has been suggested are determined by his experience (Ferry and Brandon 1980), intention (Keating 1977) and feel for costs (Chartered Quantity Surveyor 1982).

It was indicated by Morrison and Stevens (1981), that this value judgement aspect could be excluded in the development of a forecasting system. This argument is not accepted here, for the subjective element is seen to be an important input in the estimating model.

It may be suggested that in an orderly world in which free will exists, the uncertainty of prediction of the future arises not out of the possibility of free will, but out of the inability to have perfect knowledge and the possibility of irrational action.

Further, Heisenberg (1963) has stated that every description of nature contains some essential and irremovable uncertainty. Thus we can never predict the future with complete certainty because we can not be completely certain of the present. Hence, no explicit statement, no communicable language can formulate generalisations which are more precise than the common agreements between those who use them. So one cannot make scientific laws or develop cost models which have a greater finality than the measurements and rules which we share.

The above would indicate that in cost estimating as in any other predictive action one should avoid the temptation to attempt to develop the 'intellect' identified by Laplace (1961):

> "An intellect which at a given instant knew all the forces acting in nature and the position of all things of which the world consists - supposing the said intellect were vast enough to subject these data to analysis - would embrace in the same formula the motions of the greatest bodies in the universe and those of the slightest atoms; nothing would be uncertain for it, and the future, like the past, would be present to its eyes".

In seeking to resolve the dichotomy between the success of the traditional approaches to estimating and their (now) revealed limitations one is left to conclude that while the world is not absolutely deterministic and the actor (cost estimator) cannot be divorced from it, there remains sufficient causality in the world and constraints upon an actors actions, (e.g. experience (Ferry and Brandon 1980), intention (Keating 1977) and feel for costs (Chartered Quantity Surveyor 1982) to suggest that fruitful developments in cost estimating will result from an investigation of the relationship between the cost estimator, his knowledge and his information base, for while it is accepted that it is not possible to have perfect knowledge, knowledge is a function of information and by improving information one improves knowledge.

Limited information about the proposed building and thus ambiguity in the design grows hand and hand with ambiguity in the estimate.

It is suggested therefore that the act of estimating is dependent upon the availability of information of the correct quantity, quality and type, the suitable formulation of that information and the application of suitable interpretive techniques. For, while more information is not necessarily good information it is true that limited information will result in limited knowledge about the estimate. As Flanagan (1980) has noted, "One of the shortcomings of the quantity surveyors techniques in collecting and analysing data is the lack of a suitable system of identifying the significant factors that influence families of prices". Hence, if one wishes to improve one's ability to predict the future, then one should seek to do so by improving that information upon which estimates are based.

In summary therefore, if one wishes to improve predictability of the future, then one should seek to do it by improving information. That information upon which estimates are based, for, irrational action results from either a real misunderstanding of that information, or a genuine irrational act based upon the confusion generated by that information, or an irrational act which occurs because of the lack of information upon which to base a value judgement.

The argument of Blakeslee (1980), that the right brain is used to analyse the large mass of information necessary for the estimating process and make a judgement in one step is no argument for a large mass of information but rather an indication of the need to improve the quality of this information in order to release the brain for the purpose of arriving at a consistent value judgement.

More information is not necessarily good information and therefore feedback mechanisms should operate within the parameters of the information required for the particular form and purpose of the estimate, for as Park (1972) has stated "the human mind is hopelessly inadequate to cope with even a small part of the available information.

## 1.2 Estimating Philosophy

The above noted limitations to the ability to predict future costs have not restricted the arguments made by some researchers who have assumed that future costs could be determined. Much of this work has been extensively reviewed by

Skitmore (1986); for example, the work of Agnew (1972), Morin and Clough (1969) and Broemser (1968). While others assume that the estimate is correct on average, (Capen et al 1971). This is in conflict with the view of Friedman (1956) "... ~~the true~~ cost can only be known after the job has been completed".

While McCaffer (1976b) notes that "... different estimators will obviously assess the effects of factors on costs differently and hence a number of estimators are liable to produce a range of costs", and that this range is likely to vary from project to project. Benjamin (1969) confirms this view, "... there is no single distribution of the ratio of true cost to estimated cost that applies to all jobs without regard to the characteristics of the job". Park (1966) suggests that the actual project costs are distributed about the estimated costs. Vegara (1977) argues that this distribution is symmetrical about estimated costs with actual costs being equal, on average to estimated costs.

Naert & Weverberg (1976) suggest that "... some authors consider estimated costs as a stochastic variable and the true cost as non-stochastic ... others take the true cost as being stochastic and estimated cost to be non-stochastic".

However as Fine and Hackemar (1970) note, "... estimates are guesses at future costs and accounts are guesses at past costs". In their view, the two variables may not be strongly causally dependent, certainly as far as feedback is concerned", and "in theory the estimators guess should be based on accounting data and should be obtained from these by a process of data manipulation and calculation. In practice data of this kind are of little concern to anyone involved in the process" (Fine & Hackemar 1970).

The value of good estimating remains and has been identified as; "the greater the underestimate the greater the actual expenditure, the greater the overestimate the greater the actual expenditure, the most realistic estimate results in the economical project cost (Ogunlana 1989).

## 1.3 Cost Estimating

It has been argued by Ogunlana (1989) that cost estimating is prone to error for two reasons, "First it depends on historical cost data. ... Secondly, cost estimating attempts to predict future human actions in a world where things are never static".

Morrison and Stevens (1981) amongst others have suggested that despite these difficulties quantity surveyors are not as accurate in estimating as they could be.

The above reflect attempts by the design team to predict the contractors tender figure which in itself is a value based upon a contractors anticipated expenditure plus or minus a mark up.

Given that the contractors attempt to predict, suffers from the same external influences as does those of the design team while having more control over internal influences there will be no true expenditure figure. Thus the difficulty of the design team's attempt to predict is likely to be compounded.

If it accepted that a value of true cost does not exist, then it must be accepted that accuracy is a relative term. However, accuracy and efforts to achieve accuracy remain desirable in any attempt to know more about the future.

The work of Skitmore (1985) is relevant here. It has been suggested that the impact of design decisions is non linear (Fletcher 1974). Thus the initial design decisions of construction type, size, shape and quality determine the major part of the cost allocation. The later detail 'information' being much less significant (Sharp 1974). Hence the additional information provided at a later stage is assumed to be not significant. The truth of this statement will be investigated later for as in other work in this field no precise definition is proffered as to the understanding of the term information. It is hypothesised that improved information definition and quality would not only reduce the variability of the contractor's estimate, but also in consequence, the design team's estimate.

(2) $$E_{acc} = f(I_q)$$

This is confirmed by Ogunlana (1989) who notes that the major areas for improving estimating accuracy are; "increased information use for estimating, computer applications, development of expertise and expert systems for estimating, construction simulation and resource based estimating at the design phase (Morrison and Stevens 1981, Beeston (1983)". Though not stated, all of these proposals would fail if the information needs are not adequately defined and provided. For as Ogunlana (1989) later states "Error in design estimates originate mainly from the use of incomplete or unreliable information for estimating and inaccurate predictions about the construction environment".

The effect of forecasting accuracy at any stage of the design process has been investigated by a number of researchers with resulting differences of opinion. These results have been reviewed by Skitmore in a number of publications (Skitmore 1986, Skitmore and Tan 1987, Ashworth and Skitmore 1982) as well as by Ogunlana (1989) and no attempt is made here to further review these works. Barnes (1974) offers a coefficient of variation of +20% to -40% at the feasibility stage, reducing to +10% to -20% at detail design, though consistent definitions of design stages and the level of information detail are not available. Barnes' figures compare with those of; Park (1972) +-30% (order of magnitude forecast), +-10% (semi detailed forecast); Marr (1977) degree of accuracy, 20-40% (planning forecast), 15-30% (budget forecast), 10-20% (schematics forecast), 8-15% (pre-construction forecast); Keating (1977), (process plant industry), +-25% (first design stage), +-15% (record design stage); McCaffrey (1981) has produced CVs of 17% (forecast stage) 10% (brief stage), 9% (sketch plan) and 6& (detail design) for schools.

The work of Flanagan and Norman (1983), in investigating the estimating accuracy of two local authorities, indicates a pre-tender estimating accuracy of 7% and 2% for small projects rising to 10 and 12% for large projects.

Earlier work of Flanagan (1980) indicated a coefficient of variation of 15% for the inception and outline planning stage.

At the later stages of design coefficients of variation of 7% have been found (Beeston 1974), with +-10% being considered by others to normal.

Morrison and Stevens (1981), provide a coefficient of variation of 13 % with McCaffer (1976) providing a similar value of a coefficient of variation of 13.3% for Belgian data.

A hypothesis can therefore be made that as more information becomes available to the design team, estimating accuracy improves. Unfortunately, this hypothesis appears to conflict with that given earlier. Ashworth and Skitmore (1982), arbitrarily suggesting a figure based on previous research of

15 to 20% in the early design stages, improving to 13 to 18% at the pre-tender stage. Though this result may well be a consequence of the confusion of 'data' with 'information', for if significant 'information' had been provided then one might have expected a greater reduction in uncertainty and a consequent improvement in estimating accuracy. However, as Ogunlana (1989) has suggested "There is thus prima facie evidence suggesting that the cost data used in estimating is inherently inaccurate to some degree. This significantly affects the ability of design estimators in making accurate cost predictions".

Shannon and Weaver (1949) have defined the information in a message as the difference between two entropies or uncertainties: one that is associated with knowledge X before a message and the other that is associated with knowledge $X^1$ after a message.

(3) $$I = S(Q/X) - S(Q/X^1)$$

Where Q is the well defined question, I is information and X is knowledge.

The information content in a message is therefore a measure of the change in the observers knowledge and consequently his uncertainty.

(4) $$E_{acc1}\ E_{acc2} = f(I_1^2)$$

Investigation of factors which may influence estimating accuracy has been carried out. Homogeneity of data would intuitively appear to be important. The work of McCaffrey (1981), McCaffer (1976), Flanagan (1980) and Morrison and Stevens (1981) supports this claim.

A further factor which may influence estimating accuracy is that of building size. Here again there appears to be differences of opinion among those in the field. Morrison and Stevens (1981) have suggested that accuracy improves a small factor as projects increase in size. McCaffer (1976) concludes that building size has no effect on accuracy and Flanagan and Norman (1983) have shown that estimating accuracy decreases as project size increases.

Other factors suggested as having an influence on forecasting accuracy include market conditions and number of bidders, McCaffer (1976) noting a decrease in estimating error commensurate with an increase in the number of bidders.

Ashley et al (1988) suggests that scope quality, information quality, uncertainty level, estimator performance and quality of estimating procedure impact upon the quality of a design cost estimate.

Another source of forecasting error is attached to subjective factors. Familiarity with a particular type of building or one client has been associated with up to 40% improvement in accuracy of forecasting (Morrison and Stevens 1981). Jupp (1981) has suggested a distinct difference in accuracy level among forecasters. In general, quantity surveyors intuitive forecasting ability is suggested to account for a maximum of 4% of the total accuracy percentage. The grounds for this suggestion are not clear, however.

Attitude surveys continue to reveal the optimistic view of estimating accuracy taken by quantity surveyors, for example Greig (1981), with coefficients of variation of 6-7% in the early stage and less than 5% prior to tender, and Jupp (1981) with a value of 5% prior to tender.

The problems of the design sector attempting to forecast tender bids is compounded by the fact that this bid figure is composed of two components which can be assumed to be combined in a number of ways.

The first way assumes that both the cost estimate and mark up are fixed for each tenderer resulting in identical bids. The second assumes that the cost estimates are equal with the mark up being drawn from a distribution. The third interpretation assumes that the cost estimate is drawn from a distribution and the mark up is fixed. The final interpretation assumes that both the cost estimate and the mark up have associated distributions. It is argued that it is this final interpretation which adheres closest to reality.

The distribution which results from the contribution of the cost estimate and mark up distribution has been found to be normal or near normal for both buildings and roads (McCaffer 1976).

Grinyer and Whittaker (1973) have concluded that it is the cost estimate which contributes most variability to a bid. However, the difficulty of gaining access to estimating data has created difficulties for researchers who wish to assess this variability. assessments have been made however, and figures have been quoted which suggest that contractor's should estimate with an error of less than 10% ((Rubey & Milner 1966), and in the main +-5% (Park 1972). This figure has also been quoted in regard to the process engineering industry (Liddle 1979). Crude models have been used which indicate higher values, +-8% to +-11% (Fine & Hackemar 1970) and +-5% to +-15% (Hackemar 1970). Beeston (1974) has given a figure of 4% coefficient of variation  for one civil engineering contractor who investigated estimates performance while Gates (1967) quoted actual/estimated construction cost rates to be normally distributive with an approximate coefficient of variation of 7.5%.

As noted earlier the problem of attempting to determine the distribution and coefficient of variation of cost estimates is complicated by difficulties of access to data, and when this data has become available, it relates to won and completed projects with the associated tendency for data to be biased.

Rickwood (1972) has attributed the variability of an estimate to estimating errors which he assumes are mainly random, therefore the cost estimate is a random variable. This would appear to be a simplistic view as no attempt is made to define error or take account of the knowledge of the estimator, his experience, available information and therefore his perception of what is a correct estimate.

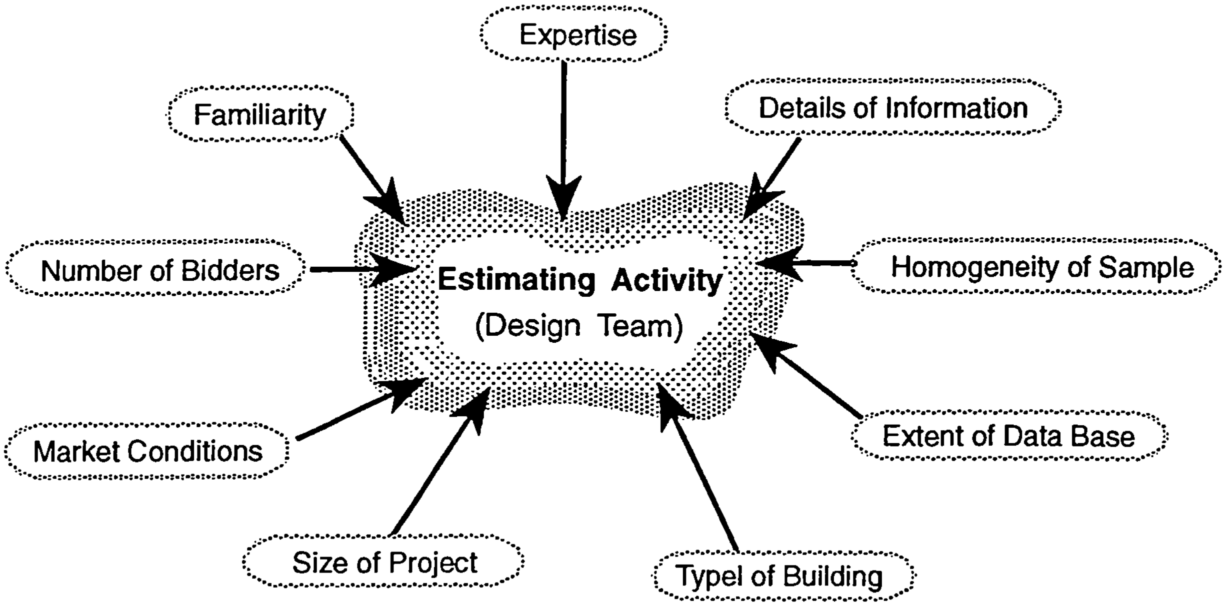
Errors (deviations from an expected norm) are often a function of information quantity and quality and this fact has been touched on by Watson (1979) who, in an analysis of 44 tenders based on drawings and specification only and 37 tenders based on bills of quantities, has suggested an improvement in estimating accuracy in the latter, due to a smaller coefficient of variation of the tender price around the designer's estimate.

Fine (1968) has suggested that difference in price between the highest and lowest bidders is about equal to the mean estimate of the labour content of the job, or the difference in tenders is caused by the costing of labour by the different firms.

The influence of labour on cost estimate and thus on bids has been confirmed by Ashworth (1977) who found that an experimental sample of estimates demonstrated a mean error of between -3% and +46% for the estimation of bricklaying hours, standard deviation of between 17 and 30%. Coefficients of variation for such projects ranged from 13-20%, much greater than the figure of Gates (1967) and Barnes (1974)

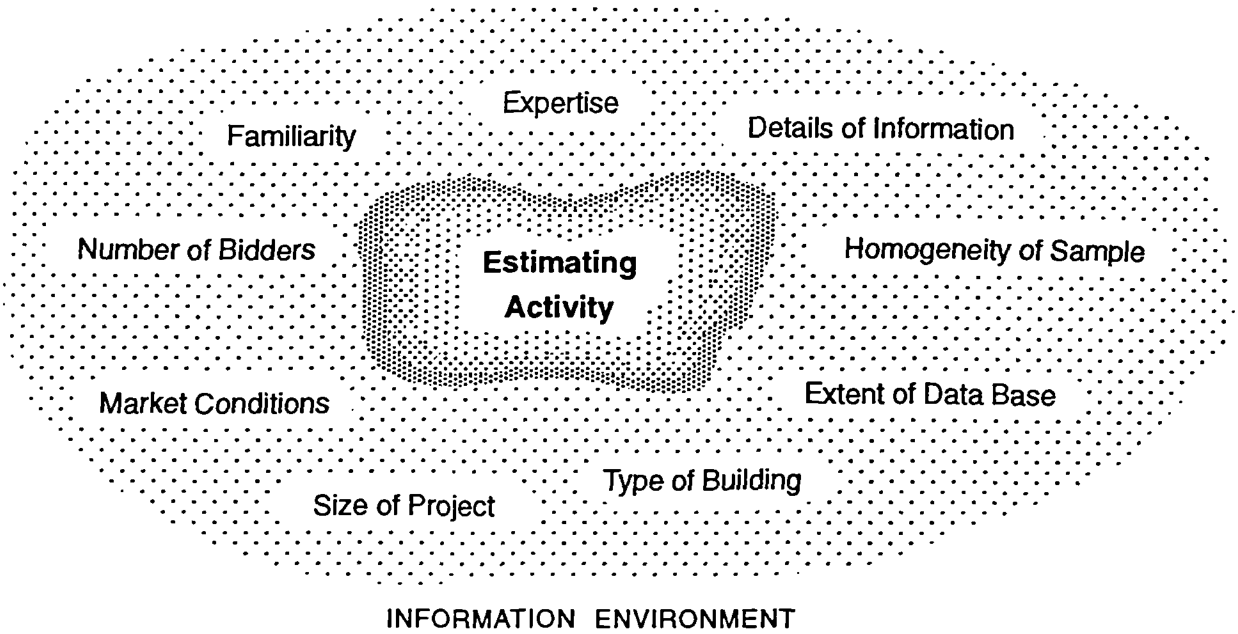
The research to date has therefore produced little reliable evidence for the confident assessment of forecasting accuracy in general, and failed to provide any indication of the extent of the influence of the main factors involved. For while factors affecting the accuracy of forecasting have been identified, (see Figure 1), and include detail of information, homogeneity of sample, extent of data base, type of building, size of project, market conditions, number of bidders, familiarity and individual expertise, no research has been carried out to determine their relative influence on accuracy.

The view taken in this research is that accuracy is a function of information quality, quantity and type and while the freedom of individuals in contractors estimating is accepted, the value judgements which take place do so within a particular environment, (see Figure 2), and are therefore predictable if sufficient information is available both for the contractors estimate and the design teams estimate. Indeed all of the criteria noted in the previous paragraph can be subsumed within




**Criteria Impacting on the Estimating Activity**
**Figure 1.**

the gamut of information. Though Ogunlana (1989) has suggested that the work of Morrison and Stevens (1981) and Beeston (1983) demonstrate that the difference in estimating method of contractors (analytical or resource based) and quantity surveyors (historical cost data) contributes to the inaccuracies in design phase cost estimating this conclusion fails to address the significance of those factors which inform the process of estimating including the specific environmental context (lifeworld - Schutz 1970) of the individual. This latter concept is alluded to by Ogunlana (1989) who has asserted that the use of resource based estimating at the




**Criteria and the Information Environment**

**Figure 2.**

design stage is unlikely to reduce error in estimating. This indicates the difficulties of modifying the information type without due consideration for the 'lifeworld' of the design cost estimator.

Research undertaken to date has singularly failed to take into account the part played by information in forecasting and as such has, it is suggested, excluded the major factor influencing forecasting accuracy. Thus the apparent contradictions in the conclusions of researchers and the lack of control over prediction for before one can control one must know what one is attempting to control. It is suggested that without a suitable model this becomes extremely difficult.

## 1.4 Change of Paradigm

It has been argued by Kuhn (1962) and Ziman (1968) that in any subject field there is a stock of data commonly accepted as true, together with agreement on theories which seem to give adequate explanations of the phenomena observed when studying the subject. Ziman states that it is this "consensibility", or ability to survive public scrutiny, which makes a subject scientific. Kuhn then goes on to make the further point that during research, anomalies are observed, tensions between theory and practice build up until finally a new paradigm is evolved.

It has been argued that conceptual cost estimating is an emerging science (Skitmore and Tan, 1987), and as such is required to go through two phases, i.e. reducing it down from systems development to techniques to theoretical development, and subsequently building up techniques from theories and systems from techniques. It is the view of some researchers that cost estimating remains at present in the former stage.

This view is not disputed here but note must be made that the choice of paradigm for the former stage ultimately determines the theoretical development and consequentially the systems developed. In an emerging science it is essential that one particular paradigm does not predominate to the exclusion of others, for the consequence of this is for the growth of the science to become stilted. It may be suggested that the Newtonian view of science, while contributing greatly to the rigour of experimentation and to the development of the pure sciences, dominated and distorted the direction of scientific thought from the second half of the seventeenth century to the end of the nineteenth century. It was not until 1905 that new paradigms were evolved. One paradigm resulted in the theory of relativity, while the other, a new way of looking at electromagnetic radiation which was to become characteristic of Quantum Theory. The key factor to be grasped here is that without these paradigm shifts the birth of modern physics would not have taken place. It is argued here that in an emerging science it is even more desirable and indeed necessary for regular paradigm shifts to take place (Brandon, 1983).

This concept has been related to information by Paterson (1977) who notes that, "Repetitive information is parcelled up into pre-packaged blobs of information ready for use. Whilst this is necessary for survival, it is necessary to re-open these blobs from time to time to ensure that change has not made them incompatible with present needs", and "Once designed the tools restrict our activity".

The testing of any system requires at least the following: a model, a prototype or a set of hypotheses to be tested, a criterion or criteria reflecting the system's performance objectives; measures in terms of which performance criteria are quantified; instruments for recording the measure and methodologies for measuring, (Saracevic 1970). Of interest here are the criteria, measures and instruments used for the testing of effectiveness (as opposed to efficiency) of an information system. However, before this stage can be reached a rigorously defined model is required.

In the development of models or theories there is an acceptance in science of the fundamental premise that all models and theories are approximate. Methods of analysis and logical reasoning can never explain the whole realm of phenomena at once and so a certain group of phenomena or concepts are utilised to try to build a model to describe this group. In doing so other phenomena are neglected and the model will therefore not give a complete description of the real situation.

The phenomena which are not taken into account may either have such a small effect that their inclusion would not alter the theory significantly, or more contentiously, they may be left out simply because they are not known at the time the theory is built.

To specify the limitations of a given model and to develop an alternative model is often one of the most difficult and yet one of the most important tasks in its construction.

In construction cost estimating such model development has historically almost exclusively concentrated on factors of cost.

Ogunlana (1989) identifies five approaches to cost modelling; procedural, regression models, probabilistic techniques, increased quantity of cost data and resource based estimating. He also notes that there has been "no increase in measured accuracy since the various models mentioned above were developed". Ogunlana and Thorpe (1987) further note that this may be a result of; " the models may not have been adopted by professionals in the industry, or, the models may not be capable of producing better estimates as claimed by their developers when subjected to real world situations".

The work of Skitmore and Tan (1987), are reflective of the cost based approach to research into cost estimating, "In cost estimating, the basic facts of interest concern accuracy, the cost of achieving this accuracy and the trade off between the two". While accepting that these features are "central", they are not exclusive, indeed it is suggested that the central feature is information and its associated communication process.

Skitmore (1986) notes "the combination of lack of relevant information and lack of time seems to be a big factor in restricting the use of formal decision systems".

He also notes that the "fundamental cause of all errors is in the discrepancy between the prototype and the model", where the 'real world' is defined as the 'prototype' (after Aris 1978) and the individual's perception of the real world is defined as the 'model' (after Kelly 1955). He concludes that "compositional discrepancies between the prototype and the individuals model are due to the prototype information received or not received by the individual together with the individuals ability or inability to model the prototype once the information is received". Interdependencies are known to exist between the prototype, the individual and the information, (Schutz 1970, Skitmore 1985).

These discrepancies termed "uncertainties" by Skitmore (1986) have been suggested as being a consequence of "inherent uncertainty" (Bennett & Barnes 1979), "chance variations", (Gates 1971), "chance events", (Woodward 1975) or "lack of predictability", (Ireland 1985) in the prototype. "Inherent uncertainty is therefore intended to represent the cause of those errors which cannot be avoided in any way in other words, the limit to which the model can approximate the prototype" Skitmore (1986). The result therefore is "an inherent inability to forecast positively the efficiency, and therefore the production rate for any given crew for any given operation", (Gates 1971, quoted in Skitmore 1986).

Skitmore (1986) seeks to distinguish between uncertainty and risk by suggesting that risk is "Some knowledge of the nature of the prototype/model misfit", and that this may be quantified in some way, whereas uncertainty cannot. However no suggestion is made as to the methods to be utilised in order to quantify the risk and indeed it may be argued that within the context of information, so little is known of the nature and form of information and its impact upon decision making that it is a factor of uncertainty rather than risk.

## 1.5 Information Improvement, Risk and Uncertainty.

It has been argued that there are two approaches to dealing with risks and uncertainties. One approach is to devise methods of exploiting the situation by adopting a more flexible posture. The alternative is to reduce the effects of risks and uncertainties by either reallocation or by improving the prototype/model fit (Skitmore 1986). Improving the model fit involves either changing the model or changing the prototype in some way.

It has been noted that uncertainty can be defined as a lack of information about the environment while in the context of research into accuracy of cost estimating Ogunlana (1989) defines uncertainty as "a lack of information about the task or task environment".

The quality of the model is dependent on the ability of the modeller and the information he receives depends upon this contextual state. This ability being a function of the modellers 'sedimentation' of knowledge, (Schutz 1970, Lansley et al 1980).

The quality of information is not only a function of context but also the shared experience set of the sender of the information and the receiver of the information, (the modeller) (Shannon and Weaver 1949).

Skitmore (1986) suggests that "information, cost, time and the ability of the selector are important aspects", however, the impact of information upon the ability to reduce uncertainty or risk has often been dismissed, minimised or simply avoided, "the amount of information available is not necessarily the only factor in the determining the level of accuracy", (Skitmore 1985). While Ogunlana (1989) makes the dubious statement that, "contractors estimates benefit from relatively more complete information than design phase cost estimates",.

In researching cost estimating it has been suggested by Skitmore (1986) that the work of Benjamin (1979), Neil (1978) and Ashworth and Skitmore (1982), demonstrates that the extent of complexities and uncertainties in the process results in accuracy being determined more by the ability of the predictor than the project information available. Unfortunately no evidence is given for this conclusion and indeed it remains unlikely that such a dichotomous approach to ability can be upheld, (Schutz 1970).

Further, "little is known of the abilities demanded of the modeller except that experience, training and perhaps some innate characteristics are beneficial. Informational requirements are on the other hand rather better known. information directly relevant to the problem is however never complete. Some kinds of information are either too costly to obtain or simply unobtainable", (Skitmore 1986).

Yet, reference is constantly made to information, "there are no specific figures available in the literature concerning accuracy levels achieved (in estimating) and some research in this direction particularly in relation to project characteristics, the abilities of the predictor and information used would be advantageous (Skitmore 1986), and, "The information available for predicting the extent and nature of the tasks is contained formally in the tender documents in the competitive situation. These, in the UK may comprise the drawings and specification and/or bills of quantities. The accuracy of task predictions has been found to be affected by errors and omissions in the drawings (Ormerod 1984) or by misinterpretation of contract requirements (Gates 1971) over, for instance, the suitability of "equal substitutes", (Gates 1971), or "quality of work", (Moyles 1973); (Bennett and

Ormerod 1984). Mistakes occur through computational errors (Langford & Wong 1979) and omissions and commission, (Gates 1971). Quantity errors are of particular concern (Langford & Wong 1979) resulting in undermeasurement or omission of items (Park 1966). The generality of quantity descriptions also provides a source of error, the extent of which has been said to be dependent on the level of measurement (Bennett and Barnes 1979). It is possible however that missestimates in quantities can sometimes be anticipated (Stark 1976). Many criticisms have been made of the lack of association between quantity items and the nature of the construction task. Task orientated quantities have been proposed to improve predictability (Flanagan 1980 and Thompson 1981)" (quoted in Skitmore 1986). Also Lavelle (1983) has noted that "The criteria for selective choice of estimate information should be investigated". Ogunlana (1989) notes "The view in construction literature is that the accuracy of estimates should improve as design progresses. The estimator has more information on which to base predictions and (the) project is better defined than at the early stages of design".

A paradigm for cost communication in the construction industry should reflect, or should allow the interpretation and measurement of costs. The purpose of this research is to develop a model of the communication process in order to reveal the information requirements, information needs, information relevance, influences upon an estimators ability to interpret and utilise this information and the ability of the present communication process to provide the necessary information to support the estimating process.

"I believe that notion of the "quantity of information" is a Big Idea in science, similar in scope to the precise definition of "the amount of matter" as registered on a balance or the "amount of energy" as derived from the potentials, velocities and heat, or the "amount of entropy" as derived from the probabilities of the states of a system", (Rapoport 1953).

## 1.6 Paradigm Development

Analysis of a system suggests a need for: a model, a prototype, or a set of hypotheses to be tested; a criterion or criteria reflecting the systems performance objectives; measures in terms of which performance criteria are quantified; instruments for recording the measures; and methodologies for measuring.

Many systems contribute to the conceptual models of the final building product, from the viewpoint or perspective of a particular process. Depending on the process, such as designing, quantifying, estimating, planning, etc., the information required for that process is supplied and defined by its associated information system.

At a specific point in time, with a specific information system, it is possible to draw a boundary between the decision making system and the information providing system. The information is determined by a previous decision and the subsequent information used for a decision. The way in which it is used is determined during decision making.

If decision making is included in the system this suggests including decision making rules. Thus, to evaluate a system would require evaluating the performance of people in interpreting information and making use of this information. It may also be argued that as individuals change so do their attitudes and thus the individual difference of performance in interpreting information is of limited concern when deciding whether to improve an already formalised information system. Hence the analysis will concentrate on the ability of the information providing system to provide the relevant information in an easily and unequivocally interpretable form. The basis of the evaluation should be the quality of the information provided by the system, but ultimately this cannot be divorced from the individuals perceptions as determined by his contextual state (Saracevic 1970) and the sedimentation of his knowledge (Schutz 1970).

It is considered that the essential information problem is that which results from the separation of the design and construction process, (Cunningham, 1984), i.e. the problem is one of 'communication' as evinced in the need for communication documents, i.e. drawings, specifications and bills of quantities. As noted earlier communication of knowledge is effective when and if information that is transmitted from one file results in changes in another.

This gives a guide as to how to proceed to with the later experimental analysis, for the quality of information and the effective communication of knowledge may be judged by the changes which are effected in those functions which are the receptors of the information.

It is however necessary as a precursor to the investigation to to identify or develop a suitable model of the information system and the associated communication process which would allow the efficiency of the process to be qualitatively and quantitatively assessed.

To create a model for reviewing and relating the overall communication process and indeed the relevance of the information contained one must first consider the process of communication.

This research seeks to develop such a model. In doing so, it will reveal the key inputs to the process, the outputs and the relevance of the process inputs and outputs to the individual and to the estimating function. It will argue a case based upon research findings for the adoption of the model in further research into information needs, provision, utilisation and efficiency within the context of estimating.

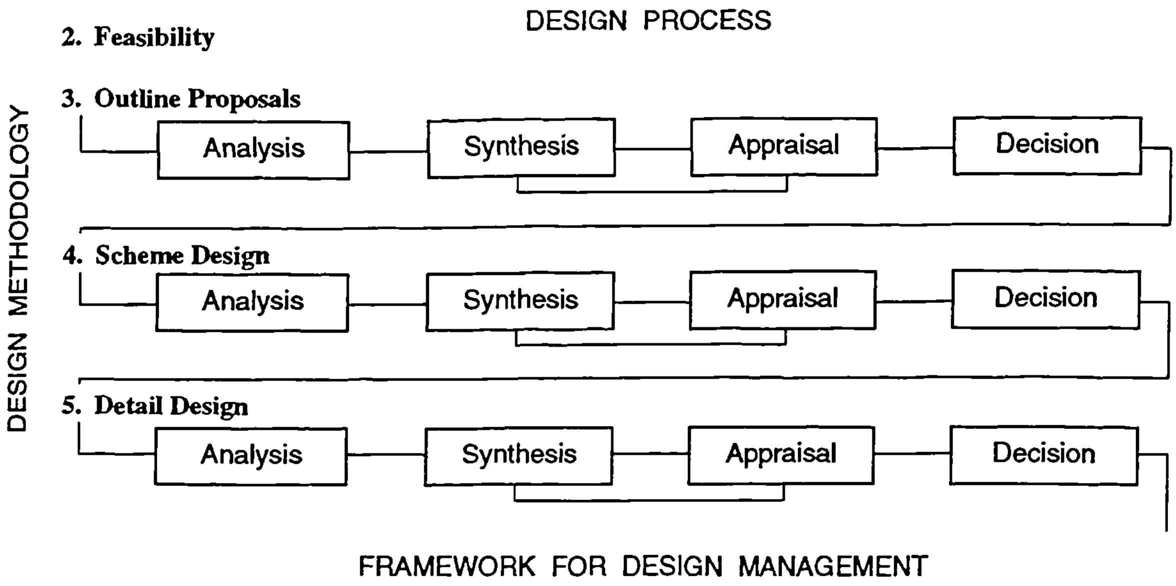
# CHAPTER 2

# DESIGN AS A NEGATIVE ENTROPY PROCESS

## 2.1 The Design Process

Over the past thirty years the participants in the Building Industry, and their associate information systems have become more selective in the dissemination of information, supplying to each other only that which is necessary to support it. It may be argued that participants have lost sight and significance of their roles in the overall structure and communication process of the industry and, to some extent fail to appreciate the effect they have upon it (Cunningham 1984).

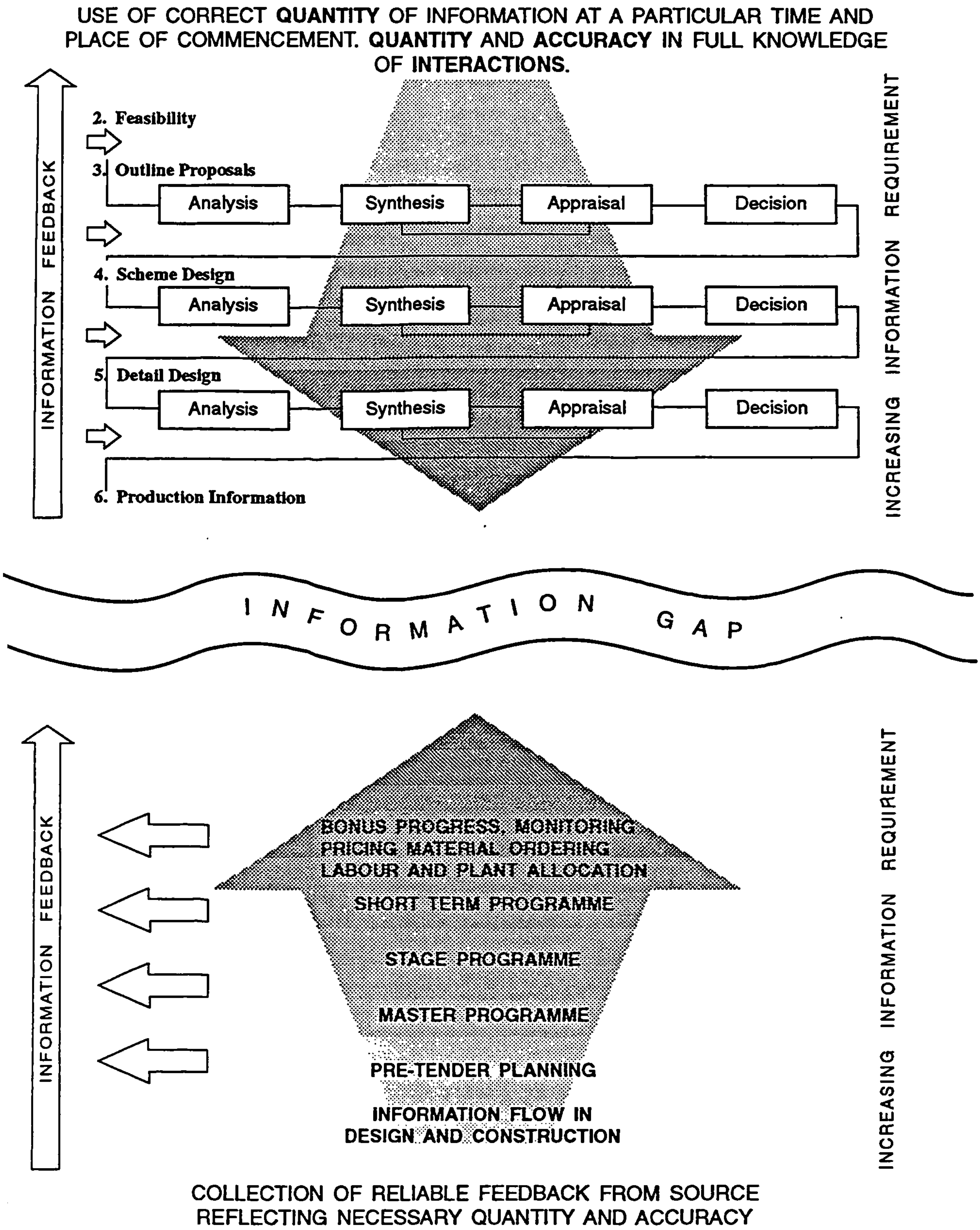
The process of designing and constructing buildings consists of a series of stages, going from inception through to completion and use of the buildings (BPRU 1972). This is a vertical sequential series in which any return to a previous stage can be considered as a failure in the management of design, (see figure 3). This is a process of moving from the abstract and variable to the concrete and particular, as such it is a movement toward order and organisation. The process is therefore one of attempting to reduce the entropy of the design concept as an effort is made to reduce the design possibilities and increase the design probabilities (Rappoport 1953) (see figure 4).




**B.P.R.U. Model**

**Figure 3.**

It was Clausius (1872) who propounded the two laws of thermodynamics which was the initial context in which the concept of entropy was elucidated. The first law states that energy is conserved, it is not created or destroyed. The second law states that while energy does not alter its total quantity, it may lose quality. The name Clausius gave to the measure of this loss of quality was entropy, from a greek root meaning 'transformation', which can be understood within the context of this thesis as that transformation which occurs when the client transfers his objectives into a brief which is then transformed




**Design Information Model**

**Figure 4.**

into drawings by the architect, thence by the quantity surveyor into a bill of quantities and thence once again by the contractor into a set of operations, materials and resources.

Entropy at each stage of the design process is lowered by the input of information, by the further definition of the model, BPRU (1972), Hardcastle, (1978). Without this input of information there is no lowering of entropy.

Another way of looking at the second law of thermodynamics is that the higher the entropy, the more numerous are the possible ways in which the various parts of the system may be arranged. Though not explicitly related to the concept of entropy by the author, this fact was demonstrated in relation to bills of quantities by Fine (1968).

"A system which could initially obtain $P_0$ different structures, all of them having equal a priori probabilities. With the information, the number of possible states is reduced to $P_1$, and we take the logarithm of the ratio $P_0/P_1$ as a measure of information. Initially, information $I_0 = 0$; number of possible structures $P_0$, finally information $I_1 > 0$; number of possible structures $P_1$",

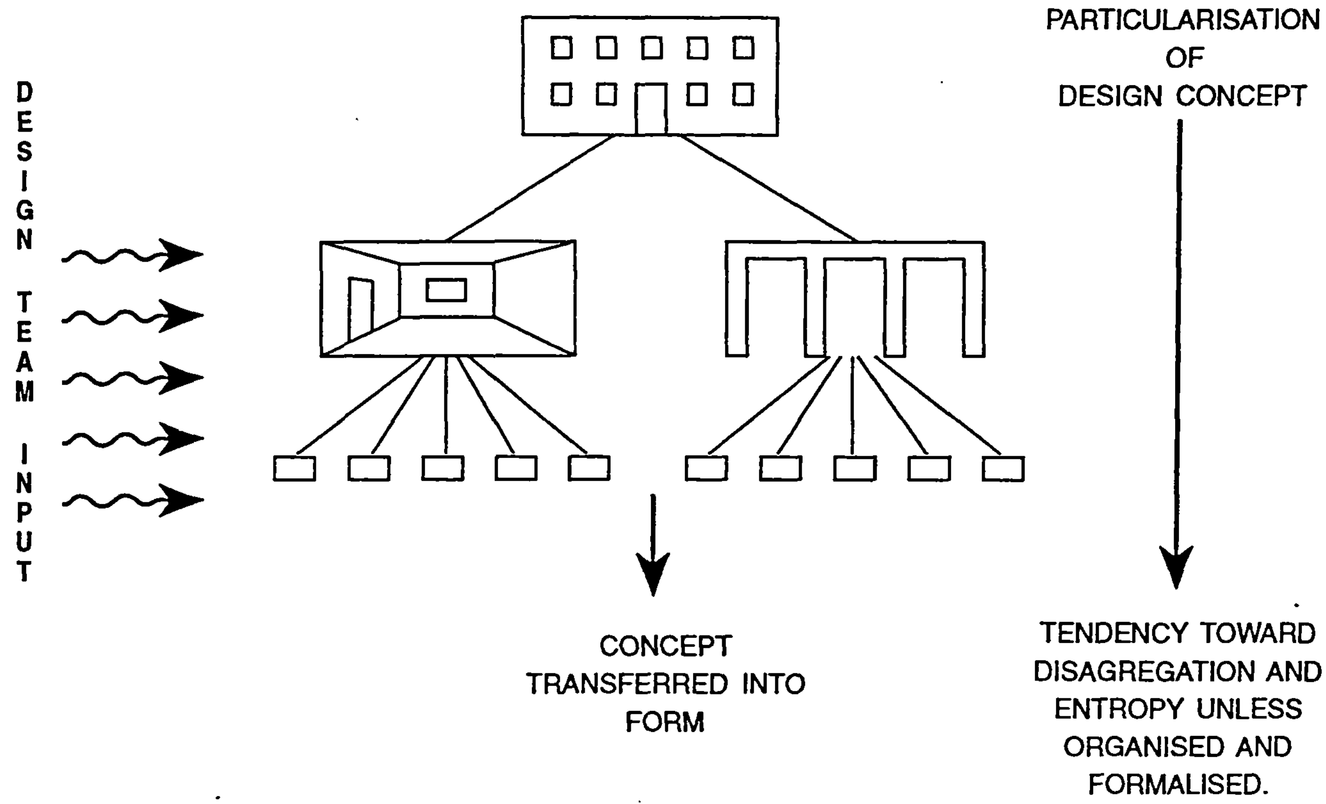
(5) $$I_1 = k \ln P_0/P_1$$ (Brillouin 1953).

The coefficient k will differ according to the information system.

Essentially within the design context this may be viewed as being analogous to the requirements of the information systems as the design process extends through time. For while in the initial stages the model definitions of function, size, location etc. (Morrison and Stevens 1981) are sufficient to allow initial cost estimates to take place, the development of the design process requires more specific identification of the particular elements and components. That is to say, that for the purpose of either pre-tender cost estimating by the design team quantity surveyor, or tender cost estimating by the contractor's estimator, the possible parts of the model have increased such that a need is felt for further definition. This definition must come about in the form of contractual documentation (Hardcastle 1978), (see figure 4).

## 2.2 Entropy and Information

It was Boltzmann (1894) who first pointed out that entropy may be interpreted as 'missing information'. It was Shannon (1964), who in looking at the problem of communication, arrived at a conclusion which was identical to that of the formula for entropy established in the science of physics of the nineteenth century. The equation was a mathematical expression of the



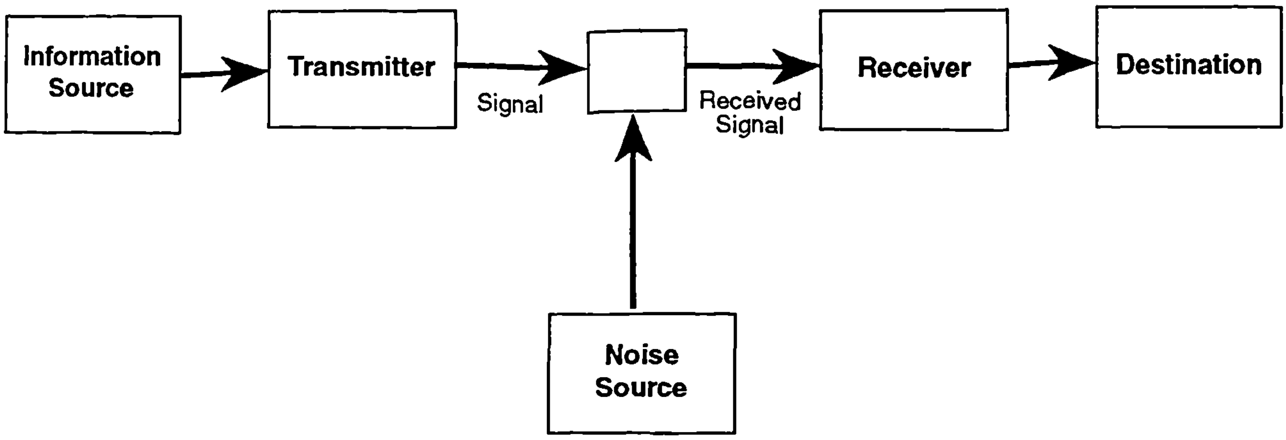

**Entropy and Design**
**Figure 5.**

tendency of all things to become less orderly when left to themselves; for energy to undergo certain transformations in the natural course of events, making it more disorganised and less useful, degrading its quality, without diminishing its quantity.

Shannon used a special diagram of the communication process, involving sending messages in discrete signal codes over a channel from a source to destination (see Figure 6). In his view the amount of information transmitted in such a message is a function of the predictability of the message. For instance a source which responds 'yes' to every question conveys no information by that message.

Brillouin proposed equating information with 'negative entropy' (1953). He defined negentropy as the information required to change a system from one state to another more ordered state.

As a design develops from brief, through outline proposals to scheme design and detail design and so on to contract documentation, it may be argued that the design process absorbs negative entropy in the form of ideas translated into hard copy documentation (information). If it did not do so, the situation would arise in which the design concept is complete but the entropy of that concept has also increased to such a level as to result in conveying little or no information, i.e., while at the brief stage it may be possible for a cost adviser to offer an estimate on the basis of an approximate area and an outline specification he would not wish to do so at design completion with the same limited level of information. However at this point it should be noted that a comprehensive definition of what constitutes information has not been produced by previous researchers in the field of construction cost estimating. This has led to simplistic and misleading statements and doubtful conclusions often as a consequence of the lack of distinction between 'data' and 'information'. The work of Reading (1981),




**Shannon Communication Model**

**Figure 6.**

Beeston (1983) is quoted by Olungana (1989) as advocating the use of more data in the preparation of cost estimates while Broomer (1992) is noted as defining a database as a "file of information or 'data', or a collection of such files". Skitmore states (1981) "The evidence of previous studies ... suggests that increasing design information results in increased accuracy but not substantially", also, "The level of information available to the estimator increases as the design progresses" and "The effect of increasing information can therefore be assessed by comparing the accuracy of estimates made in the early stages of design (conceptual estimates) with those made when the design is substantially complete (detailed estimates)". An analysis of these types of estimates has been carried out by Ashworth and Skitmore (1982, 1985) indicating a reducing to 13 to 18% for detailed estimates. Further studies by Jupp & McMillan (1981) and by Skitmore (1985) also took place in an effort to monitor the incremental effect of information on estimating accuracy.

The confusion between 'data' and 'information' can be clearly seen in the Jupp and McMillan methodology where the results were compared for the pricing of bills of quantities by three subjects using an increasing number of previous bills. The conclusion is reached that estimating accuracy improved only slightly with the increasing number of previous bills used. No improvement being observed with the use of more than three bills. Skitmore provided increasing amounts of information about the contract to be estimated in addtion to information on similar past contracts. The use of past contracts information was found to have no significant effect on accuracy levels. The provision of current project information produced an increase in average estimate levels from -5.63 per cent error (18.28 standard deviation) to 11.13 per cent error (14.59 standard deviation) with all sixteen pieces of information. In the experiments of Morrison and Stevens, a minimal improvement in the mean deviation from 19.23 to 18.48 per cent was recorded.

It is suggested here that such experimental approaches have validity only in the sense that they seek to determine the influence of increasing quantities of data on estimating, accuracy but have failed to take account of informational aspects of relevance, context, experiential sets, sedimentation of knowledge and so forth. These terms will necessarily be investigated and clarified later in this thesis but at this stage it may be useful to quote John J. Costello Jr. (1965), "Data can be numerically expressed, that is quantified, quantifiable, tabular or objective...Data is highly repetitive. Information is not highly repetitive or quantified or quantifiable; it is characterised as narrative, subjective, qualitative, textual or descriptive. Data, then, are numbers or unit facts, frequently repeated, whereas information is ideas".

In a closed system, or in the universe as a whole, each use of energy to perform work results in less available energy in the system. Entropy is a measure of the amount of energy unavailable for useful work.

Within the process of the design the useful work requirements are as such increasing as a consequence of the iterative and cyclical processes occurring in the horizontal dimension at each chronological stage of design management. Within this dimension there are four steps; analysis, synthesis, appraisal and decision which can be defined as follows;

Analysis : the understanding of the problem;

Synthesis : producing a solution;

Appraisal : establishing the performance of the solution;

Decision : choice of the best solution.

It is within this horizontal dimension that price prediction has its greatest validity and particularly within the sphere of appraisal that cost planning techniques have developed as attempts have been made to represent the design solution so that its performance may be measured (e.g. price of provision) and the third stage within appraisal, i.e. that of design evaluation can be completed.

This process can be modelled as sets of procedures which require inputs of information which are transferred to provide outputs of information. Many information systems contribute to the conceptual models of the final building product, depending on the viewpoint or perspective of the particular process. Depending on the process, such as designing, quantifying, estimating, planning, etc., the information required for that process is supplied and defined by its associated information system.

Schrodinger in his book 'What is Life', observes that living organisms feed on negative entropy from their environment (Schrodinger 1945). As long as they are able to dissipate the entropy they create (by an intake of energy), they avoid the degeneration into the disordered state of death. This situation is reflected above and occurs as a design develops.

The decrease in entropy is not an overall phenomenon in defiance of the second law, it comes about at the expense of an increase in entropy elsewhere in the system of which the living organism is a part, or if we may use the term, of which the Architect, Quantity Surveyor, etc., are a part.

In relation to communication this is confirmed by Brillouin (1953) who acknowledges that the associated (negative) entropy of a physical system is bound information.

Rapoport (1953) has suggested that the 'amount of order' is connected with probability concepts and through them with entropy, (the less order the more entropy). But it is also connected with the 'amount of information'. For example, it may be argued that far less information is required to express a design concept in the early stages of a design than would be required at the pre-tender stage simply because the conceptualisation of a design at the early stages operates on only a limited and ordered set of parameters (Bennett 1985). At the later design stages as the design becomes more particular it is essential that this particularity is reflected in hard copy documentation (information) which reflects this particularity. The alternative is chaos or an increase in entropy with consequences for uncertainty, risk and cost estimating.

It is through these notions of probability, order, and disorder that entropy is related to information. The formal equivalence of their mathematical expressions indicates that both concepts describe similarly structured events. Consider the modification of the original Clausius (1850) equation by Boltzmann (1853),

(6) $$\text{Entropy} = S = k \ln W$$

Where $W = \dfrac{N!}{N_1!\, N_2! \ldots N_n!}$

Where N represents possible states of the system, k is a constant and W is a measure of probability.

This can be compared to the model developed by Brillouin (1953) for the assessment of information,

(5) $I_1 = k \ln P_0/P_1$ (Brillouin 1953).

Both entropy and information can be defined in terms of the same kinds of variables, namely probabilities of events. Now entropy plays an important part in chemistry and in biochemistry. For example the knowledge of the entropies of two states of a system indicates whether the system can pass from one state to the other spontaneously, say whether a certain chemical reaction can take place without outside interference.

Attempts to reduce entropy in the sense of up hill reactions seem to contradict the second law of thermodynamics which demands a continuous increase in entropy, but there is nothing in the laws which says that it cannot be circumvented locally. This is the meaning of Schrodinger's remark that 'life feeds on negative entropy' (1945). To circumvent entropy one depends on an ordering process, on fighting off the general trend toward chaos, which is always present in the non-living world.

As Somenzi (1963) states "the information we need to describe an object which has a high entropy is greater (and not smaller) than the information we need for an object with less entropy; but this information is something on our part, (experience?), and has nothing to do with information "inside" the objects. The latter is simply their entropy, which may increase as a consequence of the interaction of the same objects with our means of observation, but does not transform itself directly into our information".

But to increase the order of anything means to make it describable with less information (less effort). And this process is the essence of knowledge, of science and of any behaviour where complex skills are involved. It may be argued that this is what design and contract documentation ought to be trying to achieve.

## 2.3 Entropy and Intelligence

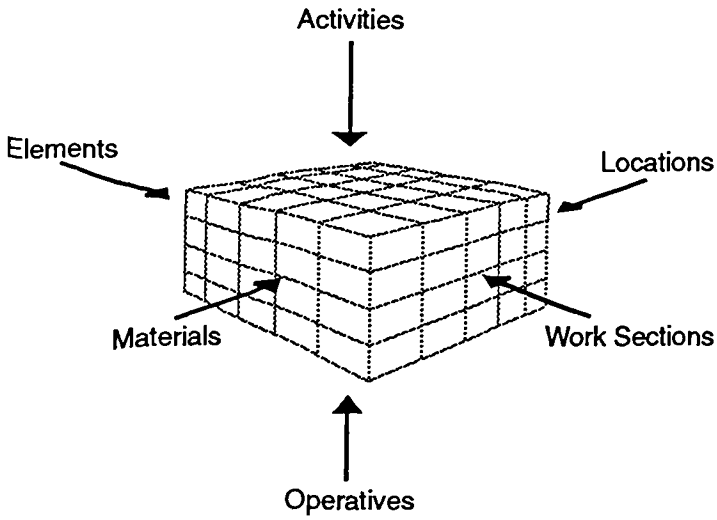
The link among entropy, information and communication was conceived in the context of communication engineering, computing machinery, and automation (Shannon 1949), and the challenge of extending the concepts of information theory remains and is traceable to its founders. It is useful, therefore, to define what the problems of extension are.

Given a set of configurations of any system with associated independent probabilities of occurrence Pi, the uncertainty of the set is defined in information theory by Shannon (1949) as

$$(7) \qquad H = -\sum_{i=1}^{i=n} P_i \ln P_i$$

(Note similarity to earlier equations)
This indicates that uncertainty increases as 'particularity' and therefore opportunity for more configurations increases. Thus if one selects a message from a source of n messages, each selection is a 'configuration' characterised by a certain probability. Then H is the uncertainty (per message) associated with the source. The receipt of the message transmitted without error 'destroys' the uncertainty of the recipient, with regard to which message will be chosen. Therefore H measures also the

amount of information per message. But, in order to destroy the uncertainty of the recipient, the 'configuration' must not only be clearly transmitted, it must also be the correct choice of configuration to facilitate an understanding of the source. In a situation where the source itself can have a number of perspectives, Cunningham (1984), (see Figure 7), the incorrect choice of perspective for subsequent configuration cannot supply the necessary information to destroy the uncertainty. In statistical mechanics, the thermodynamic quantity Entropy also appears as the same expression, where now the set of configurations are the arrangements of positions and momenta of the particles comprising a system that correspond to the thermodynamic state of the system. Once entropy was recognised as a measure of 'disorder' in a system the question of whether the second law could be circumvented by the intervention of an 'intelligence' was raised. The seed of the idea relating information to entropy was born. The idea first appears in the writings of James Clerk Maxwell (1871). He writes in 'Theory of Heat', "... a being whose faculties are so sharpened that he can follow every molecule in his course ... would be able to do what is at present impossible to us ... Let us suppose that a vessel is divided into two portions, A and B by a division in which there is a small hole, and that a being who can see the individual molecules opens and closes this hole, so as to allow only the swifter molecules to pass from A to B and only the slower ones to pass from B to A. He will thus without expenditure of work raise the temperature of B and lower that




**Information Perspectives of a Given Data Set.**

**Figure 7.**

of A in contradiction to the second law of thermodynamics. This was Maxwell's Demon. It could be argued that as the design process evolves so the intervention of 'intelligence' through the efforts of the architect, quantity surveyor and other members of the design team may reduce entropy.

Szilard (1929) has shown that in lowering the entropy of a gas by his 'decisions' Maxie causes an increase in entropy elsewhere which more than compensates for the decrease and thus vindicates the dictum of the Second Law that entropy of a closed system (which in this case must include Maxie and his apparatus) can only increase.

It has also been remarked that besides counting the rise in entropy in the gadgets which Maxie uses one must take into account the rise in entropy in Maxie himself. This in turn leads to speculations concerning similar processes in all 'organising' activity.

## 2.4 Information and Knowledge

Now consider the concept of information as a tool for quantifying the 'amount of knowledge'.

Knowledge evokes strong intuitively felt similarity to information since knowledge has been traditionally the subject matter of philosophic speculation. Accordingly one finds a wealth of discussion about fighting the inexorable second law by increasing knowledge, (knowledge=information =negative entropy).

A difficult transition is from the concept of information in the technical (communication engineering) sense to the semantic (theory of meaning) sense. This transition has been undertaken by Bar-Hillel, Carnap (1954) and others.

However, the modest but significant applications to certain psychological experiments owe their success to the fact that in each situation the set in question was strictly defined: a list of syllables to be memorised, associations to be formed, responses selected from, etc. There was therefore no difficulty in quantifying the associated 'amounts of information' and relating such accounts to certain aspects of performance.

Experimental psychology has made this beginning possible. However the gap between this sort of experimentation and questions concerning the 'flow of information' through human communication channels is enormous. So far there appears to be no theory which attributes any sort of unambiguous measure to this 'flow' in human communication systems generally and to the design-construction process in particular.

With the advent of the second law, in its purely thermodynamic form, the entropy inequality must hold. A living organism must ingest at least enough free energy, which contains a negative entropy term, to account for any local decrease of entropy concomitant to its organisational activity. This would be clear if the 'increment of organisation' inherent in a process were as clearly defined as an increment of energy. It may be argued for example that organisation is simply the negative of entropy. Entropy is unambiguously defined in classical thermodynamics, but this discipline confines itself only to processes which take place under continued equilibrium (reversible processes). The classical definition is therefore inappropriate for living processes, for as Wiener (1961) has stated, "For an organism to be in equilibrium is to be dead." The advent of statistical mechanics with its redefinition of entropy as the probability of an aggregate of states does however make possible the extension of the entropy concept to non-equilibrium states, indeed in information theoretical terms, thus suggesting that it may be possible to calculate the 'amount of organisation' of configurations arising in the living process.

Raymond (1950) proposes to define the entropy of a configuration by the sum of two terms, a positive one, equal to the entropy the aggregate would finally attain if left to itself (i.e. its classical entropy) and a negative term equal to the amount of information necessary to reconstruct the original configuration from equilibrium (complete chaos). This definition is attractive and indeed fits perfectly into the situation previously discussed where Maxie works with 100% efficiency pumping information (=negative entropy) into a system which starts with positive entropy only.

It is suggested however that there are grave difficulties associated with this definition when one tries to extend it to situations other than the simplest, (Rapoport 1953). The difficulty is the same conceptual one which governs the applications of information theory. What are the elements of a configuration? And what is the set from which messages describing the construction of a configuration from chaos are selected? Within the context of design and construction suggestions have been made as to what constitutes the elements of the configuration. These suggestions are considered in Chapter 3.

## 2.5 A Preliminary Model

Communication is a process where something called information is transmitted from one object to another (Goffman, 1970, Shannon & Weaver, 1949, via Aristotle). The first object can be called the source; the second the destination. A dynamic, interactive feedback can occur between a source and a destination; they can exchange roles (Wiener 1961).
Communication can be considered as process on its own, as Shannon did in information theory, or as a process affecting other processes, as Wiener did in founding Cybernetics. That is the whole environment can be considered.
As Shannon & Weaver pointed out three levels of problems can occur in communication; 1) technical, 2) semantic and 3) behavioural. Semantic problems also involve technical and behavioural problems involve the other two.

A technical model may be represented as below:

(8) $$f_{form} + f_1 + f_2 + f_3 + f_{k1} + f_4 + f_{k2}$$

It is suggested that the Signal has been historically defined (configured) by the Facet/Attribute requirements determined by the demands of the industry as defined by experts and weighted by practising professionals, (Cunningham 1984). This signal should have maximum information and minimum entropy for the specified context. The context in this case is estimating.

Thus in the context of estimating and with the purpose of improving accuracy;

when $$E_{acc} = f(I_q)$$

(2)

and $$I = S(Q/X) - S(Q/X^1)$$

(3)

and

(4) $$E_{acc1} > E_{acc2} = f(I_1^2)$$

It is essential to maximise the information $f(I_1^2)$ supplied in the signal and consequentially reduce the uncertainties or probabilities

(9) $$I_1^2 = f_1^2 \text{ form}$$

The Signal is initially a function of the concept transferred into form, (Hardcastle 1978). The form being the Architect's interpretation of the Client's brief in terms of functional, spatial, environmental, physical, structural and aesthetic parameters. In the perfect world this form would contain maximum information (as defined later) in that the design is complete in concept and definition, i.e. no further design or description of design either in drawn or specification form is required.

In the development of the Operational Bill it was envisaged that the Signal (i.e. the Bill) would contain other facets of information beyond those extracted directly from the Form. These were to be clear and specific indications of the dynamic facets of production, i.e. labour and plant as defined by operations.

As we progress from the idealised position of maximum information being contained in the Form of the building to that position whereby a signal may be generated which allows Contractors to Cost Estimate a project, we are moving through Encoding and Transmission stages such that the entropy of the Signal is reduced from that which would be the case were Cost Estimating to take place on the basis of the Form only.

What is occurring here is that the context has changed from that of the conveyance of an image which reflects the client's brief in terms of the factors noted above to that of Contractor's Cost Estimating.

If the context were to change without an associated change in the organisation and structure of the information contained in the Form then the Information content would be considered to be inadequate and the Entropy would have increased. In order that this situation does not occur then it is required to view the Form as an information source which can, via input of knowledge be transformed such that the Information value does not reduce but remains at an optimum level and the Entropy which had increased as a consequence of the change of context can be reduced to a minimum.

In the classical interpretation of Entropy it is assumed that its value can only be reduced by the addition of Information. The view taken here is that much of the information is already available in the previously defined Form (Cunningham 1984). What is required is the application of knowledge to dissect and aggregate this information in a manner suitable to the context, (Hardcastle et al 1985) and relevant to the user.

(10) $$I_1^2 = f_1^2 \text{ form} + k_1^2$$

Where 'K' is applied knowledge

The application of this knowledge is structured and formalised by the dictates of the various Methods of Measurement available to the Quantity Surveyor.

The quality of the Signal provided is however not only a function of the application of these aspects of knowledge but also of the other factors noted above, i.e. context and relevance.

Reviewing the diagrammatic representation of the model it can be seen that initial function which impacts upon the quality of the Signal is Form itself or in this case the extent to which Form is complete prior to the stages of Sorting, Encoding and Transmission. If this is perceived at the Sorting stage then an iterative process may ensue in which the QS will attempt to tease out further information from the designer. If this is not obtained then this information may be construed as missing information, 'M', with consequences for the encoding stage.

At the encoding stage the quantity surveyor who finds himself without adequate information with which to perform the encoding will in many cases seek via the iterative process the information required from the Designer. If this is not forthcoming he is likely to feel under the formalised constraints of the encoding mechanism, the current Method of Measurement, a pressure to use his professional judgement and knowledge to augment the information available to him. To do this, is however to mis-represent the previous Form and therefore to distort the Encoded Document. We have here a situation in which Noise is beginning to creep into the Signal.

$$(11) \qquad I_1^2 = (f_1^2 \text{ form})\ (1-M) + K_1^2$$

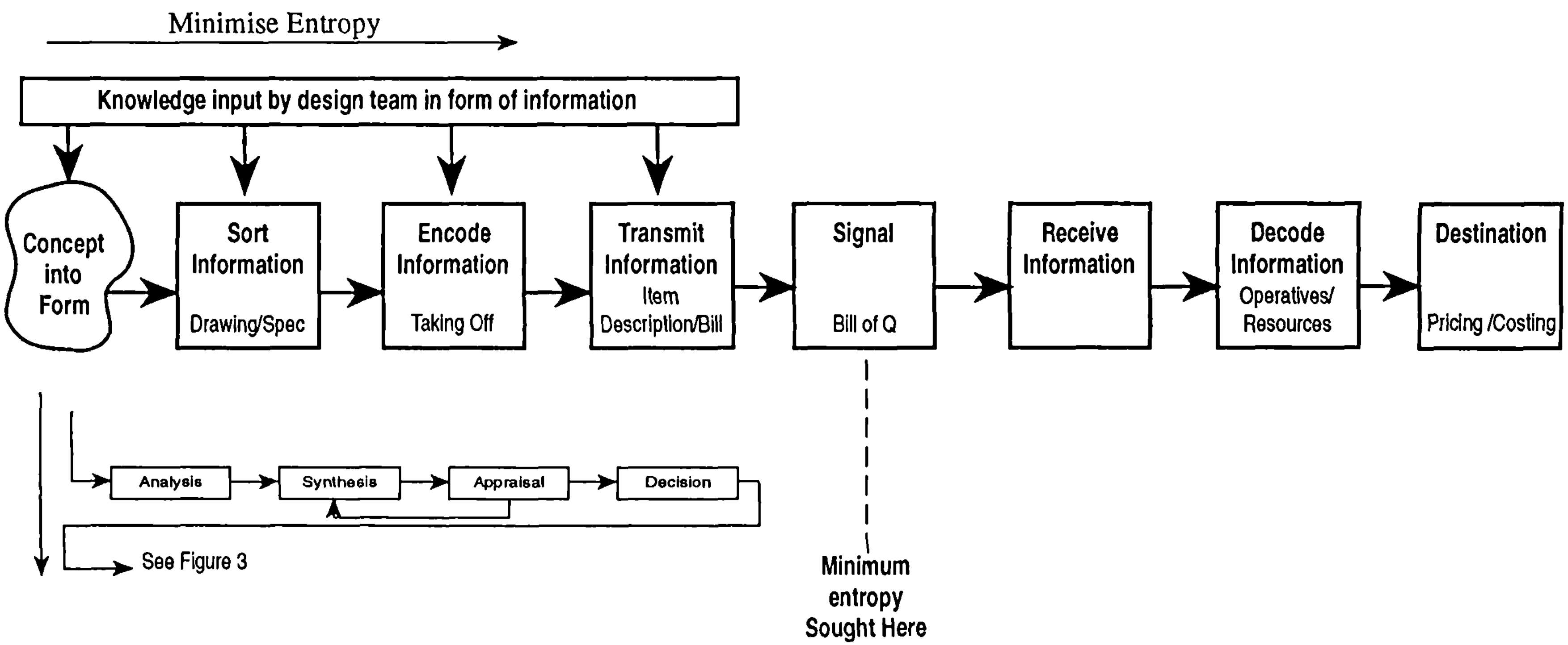
At this point we approach a difficult philosophical question. For to what extent does the knowledge of the quantity surveyor distort the encoded Signal and to what extent does the Encoded

Signal become the Form as a consequence of the input of knowledge of the quantity surveyor? In other words the quantity surveyor is contributing to the development of the Form in a valid and valuable way. The view taken here is that where the quantity surveyor has to contribute to the design of the building without prior confirmation from the Designer then that constitutes a mis-representation of the Signal.

A further type of Noise, 'D', at the encoding stage is that which occurs as a consequence of the loss of information which does exist at the Form stage but which is lost as a consequence of the formalised approach to aggregating information. Fundamentally this information is Location, an aspect which could be of crucial importance to the Contractor when seeks to decode the Signal such that he may Cost Estimate the project.

$$I_1^2 = [(f_1^2 \text{ form})\ (1-M)][1-D] + k_1^2 \qquad (12)$$

Finally, as the encoding is completed, the Signal is prepared for transmission. This is done by producing a Bill of Quantities which contains the full encoding together with the necessary phraseology to facilitate decoding by the Contractor. At this stage, while there will be no further noise likely to creep into the signal there is the possibility of a reduction in informativeness as a consequence of increasing redundancy 'R' and reducing significance.




Sort = collect + colate + organise

This is the first part of a cyclical communication process; Design Team → Contractor

There will be a return parth; Contractor → Design Team

**Preliminary Communication Model**

**Figure 8.**

These factors therefore impact upon the entropy level of the Signal as they may well not contribute further information but rather only greater redundancy.

(13) $$I_1^2 = ([(f_1^2 \text{ form})(1-M)][1-D] + k_1^2)-R$$

The information process which sees the transposition of the Concept through Form to Information Sorting, Encoding and Transmission in the shape of a Signal has to be seen within the context of Contractor's Cost Estimating. As such, we would hope that the Signal so produced would be in a form and would contain the appropriate information to facilitate the Cost Estimating process, (see Figure 8).

Thus the success of the Signal transmission must be seen not only as being judged on the basis of the minimum Noise content and minimum Entropy, but also upon the appropriateness of the information contained for the Cost Estimating process. For a Signal which contains zero Noise and minimum Entropy may well also contain zero information if it is not appropriate.

It is also necessary to determine what is relevant. For if it is not relevant then it does not matter if it lost or distorted.

# CHAPTER 3
# INFORMATION AND THE BILL OF QUANTITIES

## 3.1 Rationale

In the terms of modern theory, information is everywhere, but knowledge can only occur within the context of a goal seeking adaptive system peopled by goal seeking subsystems. It exists by means of and under constraints imposed by its context. The same information system can be related to a number of realities of a context, to a number of contexts and can perform many functions, (Cunningham 1984, Hardcastle and Middleton 1987). Thus, the role of the context in which the communication occurs and the interaction of information systems with their contexts must be considered.

The work of Skinner (1979) identified fourteen procedures in the contractors office which use the bill of quantities as an information source.

If this is the case then we are required to know how the knowledge has been coded and filtered; and what it is being used for, and for whom. The contexts which have relevance here are those which contain the appraisal processes both in the design sector and in the construction sector. In particular, the cost estimating systems and the information subsystems which feed them.

Conformity of measurement practice in the United Kingdom was achieved by production of the first edition of the Standard Method of Measurement in 1922. This was followed by revised editions in 1927, 1935, 1948, 1963, 1978, and 1988. Each new edition reflecting a desire to improve and clarify the principles contained within the document.

The initial rationale behind the the format may be understood to be a combination of historic factors, i.e. the need to produce a trade based document for a trade based industry and the anticipated purpose of the document as a contract vehicle. The view that the bill is a cost communication document has been noted by Bishop (1966) and Walker (1974). There are those however, who would seem to suggest that as a communication document its purpose is uni-directional, i.e. from designer to producer, (Murray 1972).

While it is accepted that in any contractual situation a contract document is required in order that conditions of offer and acceptance are explicit it may well be that the production of such detail at this stage of the production process is not warranted in view of the variables upon price which cannot be quantified or in some cases identified, i.e. the context is confused and the redundancy excessive.

Furthermore it has been found by Moyles (1973) that the priced bill of quantities shows the typical qualities of a Pareto distribution, i.e. 80% of the cost of a project is contained in 20% of the items indicating that the number of items may be reduced dramatically. This is further confirmed by the work of Saket (1986), and the work of Hardcastle et al (1987).

Although there may be confusion over the definition of the main purpose of the bill, other potential uses can be identified.

These are:

| | |
|---|---|
| Designer | Cost Planning |
| | Tender Evaluation |
| | Financial Forecasts and Control |
| Contractor | Standard Pricing |
| | Materials Ordering |
| | Labour and Plant Allocation |
| | Bonusing |
| | Network Analysis |
| | Construction Analysis |

The word potential is used in this context for the purpose of expressing clearly the suggestion that, although these processes can be carried out now with the bill in its present form, (consider Skinner 1979), they are not necessarily efficacious as a result of the conflict which results from the use of a contract document as a communications document in many contexts thus increasing the possibility of redundancy.

## 3.2 Information Desired

Ogunlana (1989) has identified three sources of design cost information. These are; information supplied by the client, design information from other professionals, and historical cost information generated by the estimator, while the RICS Handbook notes three sources of cost data; Cost Analyses, Price Information Handbooks, Published Indices. A major influence on the quality of this data is the feedback obtained from priced bills of quantities and the approach to this pricing process.

Crawshaw (1979) has indicated that the type of contractor has an influence on the information preferred, "the small contractor liked to negotiate most of his work and avoid pricing bills of quantities ... the medium sized contractor liked to have as little information as would allow him to price confidently. The bill was the central document and all other information was used as an amplification of the bill when needed. Large firms doing large projects were much more concerned with planning at an early stage ... so that their requirement for information was much more geared to the needs of the planners. This led the larger firms to ask for full sets of drawings even though many of the drawings proved redundant at the tender stage".

Crawshaw (1979) also notes that "the type of project can have considerable bearing on the information required at the tender stage".

Fletcher (1974) states that "Ideally a bill of quantities should provide a list of items representing, by means of appropriate parameters, sub-divisions of total cost which are pertinent to the construction process".

Paterson (1977) has suggested that the bill of quantities as a cost communication document should, together with other design documentation, provide information on: Location, Area, Number of floors in which the area is contained, Type of envelope and its shape, Division of internal spaces, Type of construction, The intensity of services, Energy input requirements, The designer, The brief. The factors which would most likely interest a contractor gives yet another list: Availability of labour for the area, Location, Commencement and possible completion date of contract, Complexity, Size of project in area and height, Size difficulties, e.g. location of stores, pumping etc. Paterson (1977) also notes that "This would probably not include materials, as he would assume that these would be measured and that he would be paid for them. he is really concerned with factors which affect the management of resources, rather than the resources themselves".

Ashworth and Willis (1987) note the following factors which contribute to the determination of unit rates; market condition, design economics, quality, engineering services, external works requirements, price and design risk, and exclusions.

However, Fine (1968) suggests that the first factor which will affect the cost, is that of regulations and other legal and administrative requirements for the type of project chosen.

Fine also notes the basic factors in costing a price are: The cost of the man, Activity time of the man, The cost of the materials, The cost of the plant, Profit (including management)

The above would seem to be confirmed by the Institution of Civil Engineers (1979) who identify the following direct costs; labour and materials, plant and transport and sub-contracts, and the following indirect costs, erection and dismantling of plants, temporary works, temporary buildings, store and yard labour, tools and tackle, welfare, insurance, notices and fees, site management and supervision, contingencies, special conditions of contract, head office overheads, finance and profits.

Bennett (1985) states that bills of quantities identify the characteristics needed to achieve project reality but, in the main, not the resources nor the factors influencing their utilisation, which is essential if optimal design and construction are to be achieved. "It is the resources which are responsible for cost generation and therefore, resource identification is essential to allow true financial evaluations to be carried out. Also, as the resources, together with their financial implications, can be easily related to the characteristics of the project, then more objective appraisals can be achieved".

In line with the above statement and at a much earlier date, Bennett (1979) stated that the main purpose of bills of quantities is best served if the information which they contain models construction costs as closely as possible. "Instead, bills provide a description of those features which are likely to have the greatest influence on construction costs in a form which is likely to be most useful to the majority of tendering contractors".

He concludes that the factors which exert an influence on items included in bills of quantities are: The construction technology employed, The relative cost of construction resources, The degree of uncertainty inherent, The subdivision of work into specialist subcontracts, The information normally provided by drawings and specifications at tender stage, The level to which detail design is normally taken by architects and engineers. He further notes that Bills of quantities should separately identify items with regard to the characteristics of quantity; time; occurrence and value, and they should lay down the extent of the appropriate parameter which is deemed to be included in the contract.

Bishop (1966) states that in regard to bills of quantities, the factors which influence performance and cost on site must be considered. These are stated as: Sequence and interdependence of operations, Constructional methods, Improvement through repetition. In interpreting these the estimator as suggested by Thompson (1983) "selects historical rates or prices for each item in the bill of quantities using either information from recent similar contracts, or published information, or 'built up' rates from his own analysis".

The Chartered Institute of Building (1982) takes the view that the Standard Method of Measurement should lead to the production of fully descriptive bills of quantities able to provide without ambiguity, all the information needed by the contractors' estimators to establish with reasonable accuracy, the cost of building the designers intention and the subsequent conversion of these costs into an accurate estimate. Other possible uses of the bills of quantities should be regarded as subsidiary and not influence decisions concerning the basic function of the method of measurement.

Similarly Ferry (1967) states that the Standard Method of Measurement should enable the measured data produced by the

Quantity Surveyor at the 'taking off' stage to be used by the contractor for construction only purposes, noting that "In order to give complete information about a piece of building work the measurement must indicate: The nature and quality of the work, Its shape, Its size, Its position in the building, Its relationship to adjoining work.

While quantifying assists the associations of similar work for pricing, in quantifying some of its identity is lost. It seems logical to divide measurement into two states: The description and identification of the work. The subsequent manipulations of the required data.

Ferry further suggests that a bill: should give as much operational information as possible, should present measurements, broken down locationally, into smaller units that a tenderer may require.

However, Fletcher (1974) states that any system must facilitate the determination of resources but not that the whole system must be based on the definition of resources.

While Walker (1974) argues for the creation of a language which would be reasonably common between the design team and the construction team.

These attempts remain rather crude in that they have not been set within the framework of a system of information communication, which necessarily requires some acceptance of commonality of perception between the sender and receiver of information (Kemp 1979), in this case the design and construction teams. This is reflected in the use of terms such as "appropriate parameters" and "pertinent" (Fletcher 1974), "market condition" and "price and design risks", Ashworth and Willis (1987), "legal and administrative requirements" (Fine 1974) and "factors influencing utilisation" (Bennett 1985).

Developing this theme and after review of existing formalised information structures in the construction industry and taking account of the work of Ranganathan (1924), Hardcastle and Middleton (1987) suggested the information defining facets were Built Environment Type, Functional Element, Form, Material, Operation/Resources and Location.

Ogunlana (1989) notes that for a contractors estimator to arrive at a suitable cost estimate the following information is required; drawings, specification, schedules, technical reports, programme of work periods for subcontracted trades, bill of quantities. He also notes that the estimator may obtain information which; relate to the contractors intended method of working, impose restrictions, affect access, interrupt the flow of trades, affect the duration of the project, require special skills and materials, have significant effect on the programme, are of major cost significance.

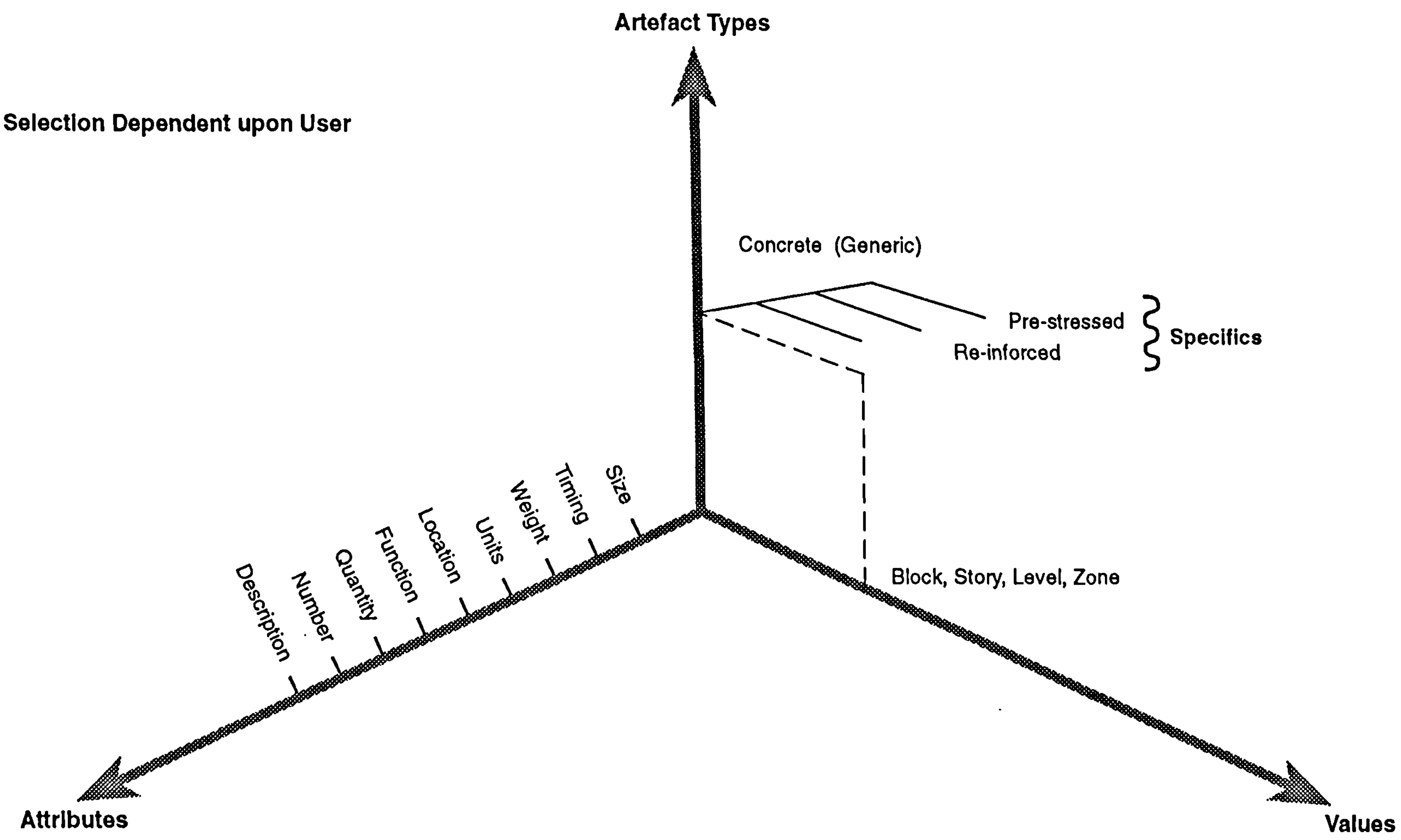
The above points to the difficulties of identifying the relevant elements of a configuration which would facilitate information exchange. How then is one to agree on a definition once and for all so as to make the entropy of a configuration unambiguous? In the case of the design and construction process this has clearly not been done adequately and there remains a need for such work in a area in which communication of information and development of knowledge is fundamental to the success of the industry. There is however a base of elements from which to work and which may be investigated, for it is the communication media of drawings, specification and/or bill of quantities which to all intents and purposes attempt to improve available information and hence the organisation and order of a conceptualised design.

## 3.3 Appropriate Information

Knowledge and information are not the only aspects that create a resolve and instil wisdom. But they are important aspects, and the complexity of the design and construction process has probably made them into the most important aspects.

It is clear from Figure 1 that a good design must have appropriate information in an orderly and timely way. One basic

Selection Dependent upon User




**Information Configuration Model**
Figure 9.

assumption is that people do need information. Nehnevajsa (1966) begins at this point and states "The question is not whether men need information, for they do. Rather, the issue is whether the information available to them is of the right kind and quantity, of acceptable accuracy, and of appropriate timeliness."

Among the fundamental characteristics of an information system are included ;
Source:- the reliability of the source of information plays a very important part in good decision making,
Quantity:- the correct quantity of information is vitally important. Having too much information may be just as bad as having too little, sometimes it is worse because one may become confused. Possibly less, more accurate information would be more beneficial.
Quality and Accuracy:- the accuracy and relevance of information varies a great deal depending on the scale and complexity of the design project and the stage at which it is to be used. Examination of the information source may reveal the quality of information while relevance of information is a function of the purpose for which the information is being supplied.
Information Interaction:- the more one understands the relationships, the interaction of information, the more one controls the amount of information collected. This in turn saves time, costs and energy. It also suggests the need for a

common experiential set between sender and receiver of information.

Time and Place:- having information at the right time and place is the essence of a good information system. The information must be collected and applied at the most appropriate stage of the design in order to exert the appropriate influence on the design.

This thesis will consider that information system which contains knowledge of costs and prices. If a client is to achieve his desire of obtaining his requirements at a minimum cost it is essential that there is a smooth flow of information between all parties responsible for the production of the building so that the iterative design process can proceed.

In the manufacturing industries the inter-related processes of objectives management and design management are often carried out in the same organisation resulting in an information system at such a level and in such a form as satisfies the accounting and estimating criteria under which the firm operates. In the construction industry a different situation very often exists. The production processes are undertaken by various parties. The separation of design and construction in particular results in a breakdown in the information flow between the parties involved. This breakdown in the information flow inevitably results in a situation in which the iterative processes of design management do not operate efficiently as the appraisal operation cannot be carried out without suitable information for the measurement operation, (Hardcastle and Middleton 1987).

It is accepted that there is an information gap between design and production in the traditional approach to building procurement in the United Kingdom. It is further believed that in line with the views of commentators such as Bishop (1966) and Walker (1974), as well as the development of the Standard Method of Measurement, there will remain a need for the bill of quantities to bridge that gap and satisfy the role of a communication medium. As such, it should satisfy the definition of a communication document in the fullest sense., i.e. "it should give a certain form or character to matter, it should be a force which shapes, conducts, trains, instructs and guides", Campbell (1983).

It is a document therefore which operates in the form of a classical communication medium though this is necessarily in a qualified form of the Chase (1954) communication diagram. In that it remains an important criterion that communication occurs in two directions (see figure 3). In communicating information, noise will inevitably occur whether this is a consequence of poor taking off, poor descriptions, incorrect use of terms, or as is most often the case, generating bills from information which does not exist in the form of drawings. In developing a model it is necessary to place these aspects of noise within the context of the overall view of information communication which includes aspects of philosophy, logic and information science and which would also take account of the significations of the information in the bill and to make recommendations for improving the quality of these significations.

As noted earlier, information is a necessary condition for signification but it is not a sufficient one for it may be seen that the typical bill of quantities contains a tremendous amount of data while containing insufficient signification and hence the suggestion is that it contains less information than it does data. Thus, while Skinner (1979) may demonstrate the uses to which the bill is put, little indication is given as to the significance of the information to the system processing it. The ability of a single document to contain adequate levels of signification for all the processes identified by Skinner, must be doubted for as noted earlier, signification depends upon context and the more context there is the more there is redundancy. Though Weaver (1964) discusses redundancy within the confines of grammatical syntax, it may be understood here to be a function of the detail of definition which is required by a contract document dictated by the Standard Method of Measurement. Such a level of detail results in high data content but little signification. Within the specific context of estimating this has been admirably revealed by the work of Fine (1968) on variation in individual bill rates. Such variation can only be fully understood if considered as a

consequence of the lack of signification of the items. For as Wilden (1972) states;
"The more any given repertoire is analysed atomistically and non contextually, the more information and the less signification the repertoire has". Within the context of this statement it would appear that Wilden is using the term 'information' to describe data, for information which is not significant is not information.

However, signification must involve shared information; the more sharing the more redundancy. This paradoxical statement is at the heart of this research, for it is the sharing of information between the design team and the production team which must occur if buildings are to be designed and built as efficiently as possible. Thus redundancy is inevitable. It is the aim of this research to view this interface with the purpose of increasing the signification of the information contained by reducing redundancy and minimising entropy, i.e. the tendency for information contained in the communication process to become disorganised and degrade. It is because of the problems of context, that this research concentrates on a specific area, that of cost estimating and the information which that process utilises.

The importance of signification is that if information is significant it is no longer simply 'data' but 'information' with a potential to reduce uncertainty.

It has been understood over time that the human mind is capable of two kinds of knowledge which have often been termed the rational and the intuitive. The latter being associated with the arts and matters of the spirit.

Rational knowledge is derived from experience of objects and events. It is the realm of the intellect which discriminates and evaluates.

Abstraction and discrimination are important aspects of this knowledge because in order to compare and to classify immense quantities of information only significant features can be taken into account.

Thus one constructs an intellectual map of reality in which things are reduced to their general outlines. Rational knowledge is thus a system of abstract concepts and symbols, characterised by linear, sequential structures. In most languages this linear structure is made explicit by the use of alphabets which serve to communicate experience and thoughts in long lines of letters. Within certain limited and defined areas of experience specialist conventions have arisen to aid the construction of an intellectual map of reality. The most obvious in the specialist area of construction being the Standard Method of Measurement.

The design and construction of a building on the other hand, is infinitely more complex where things do not happen according to absolute laws.

One can only expect an approximate representation of reality from such a procedure and rational knowledge in this context is therefore necessarily limited.

In the words of Werner Heisenberg (1963), "every word or concept, clear as it may seem to be, has only a limited range of applicability".

Wittgenstein has said, "The meaning of a word is in its use", (1969), and without meaning, there can be no signification. Unfortunately, confusion of meaning at the most fundamental level has been a factor in the limitation of approaches to cost estimating. In particular, this is seen in the confusion between 'cost' and 'price' and their associated philosophies. Indeed, Skoyles (1977) has suggested that the confusion existing in semantics is so wide spread that both words are used indiscriminately and interchangeably leading to much confusion.

As representation of reality is often easier to grasp than reality itself, there is a tendency to confuse the two and to take concepts and symbols for reality. The cost based approach to research in cost estimating may well be a consequence of this approach. However, "Words are employed to convey ideas; but when the ideas are grasped, men forget the words", Heisenberg (1963). The semanticist Alfred Korzybski (1958) confirmed this confusion with his statement, "The map is not the territory".

Using Korzybski's analogy of the map and the territory, it may be stated that ordinary language is a map which, due to its intrinsic inaccuracy, has a certain flexibility so that it can follow the curved shape of the territory to some degree. As we make it more rigorous, this flexibility gradually disappears, and with the language of the Standard Method of Measurement based bill of quantities it may be that a point has been reached where the links with reality are so tenuous that the relation of the symbols to our perception construction is no longer evident.

## 3.4 Previous Work

Rothstein (1954) proposed that the amount of organisation a system introduces can be measured by comparing the entropies of the system's input and output ensembles.

Kramer and de Smit (1977) argue that care should be taken in developing analogies between physical thermodynamics and systems analysis. They point out that organisations are open systems, interacting with environments so the similarity between theoretical information or entropy and their apparent system counter parts is not measured.

Lynch (1977) analyses the hyperbolic distribution of letters in English text in terms of Shannon's statement that message transmission is most efficient if the possible symbols occur with equal probability in the message. In an analysis of communication networks identified by writing and citing of scientific papers, Shaw (1979) evaluates the impacts of individuals on the network by means of Brillouin's measure. The degree of dispersion or diversity of the field (its entropy) is measured and compared with the measure of entropy with the field minus a specific author. Another paper by Lee Pao (1980) also uses the Brillouin function as a measure of communication among authors. The American Society of Information Science has also explored attributes of information (1979), finding intriguing correlations with the concept of entropy.

All of these, together with numerous other papers suggest that the application of the concept of Entropy in the field of communication can be worthwhile, and at this point one can quote Weaver (1964), "when one meets the concept of entropy in communication theory, he has a right to be rather excited - a right to suspect that one has hold of something that may turn out to be basic and important".

The idea of a relationship between information and entropy, implicit in the early days of the theory, is however still questioned by scientists today. However, Shannon has said, "I think the connection between information theory and thermodynamics will hold up in the long run, but it has not been fully explored and understood", and Weaver (1964) points out the importance of the association between information and entropy, if a "situation is highly organised, it is not characterised by a high degree of choice - that is to say, the information or entropy is low" quoted in Campbell (1983).

This section must be drawn to a close with a particularly apposite comment from Shannon (1956);
"I personally believe that many of the concepts of information theory will prove useful in these other field ... but the establishing of such applications is not a trivial matter of translating words to a new domain, but rather the slow tedious process of hypothesis and experimental verification".

# CHAPTER 4

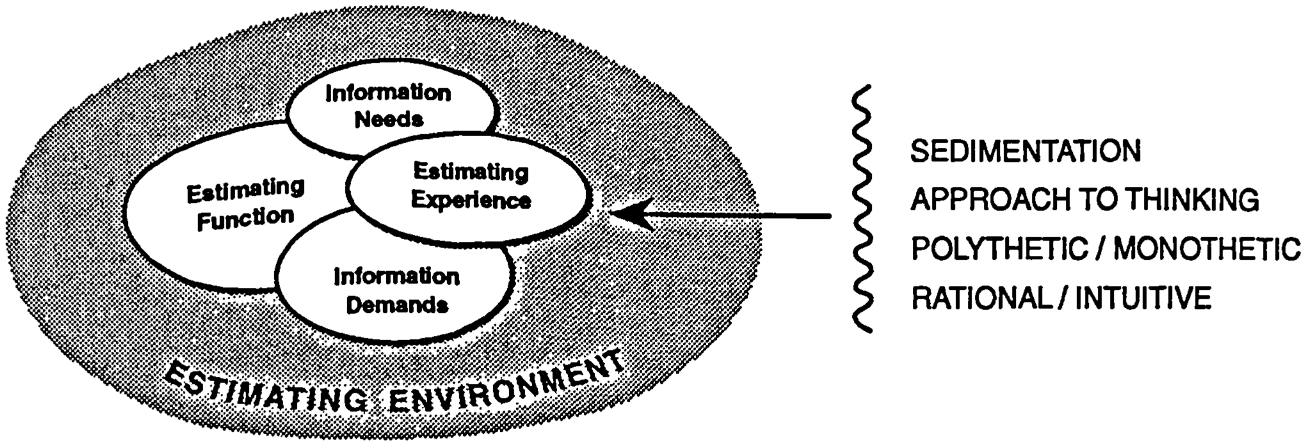
# COMMUNICATION IN DESIGN AND CONSTRUCTION

## 4.1 Information

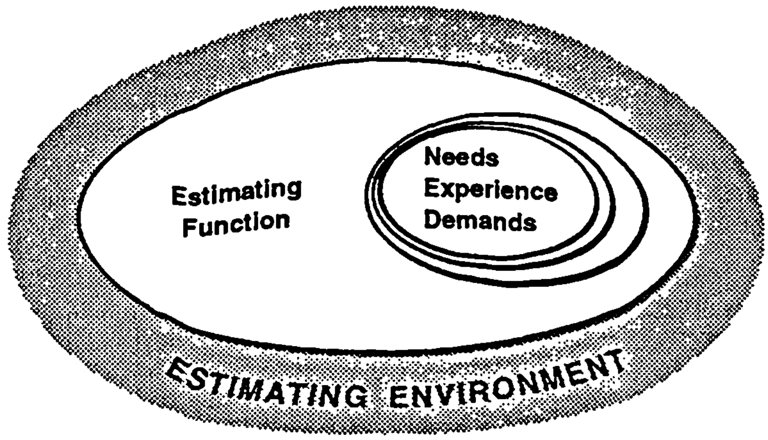
Confusion surrounds the concept of information needs. Faibisoff and Ely (1976) note that, "Words and phrases often interfere with understanding. Information needs has become an umbrella term under which a variety of interpretations fall. If information needs can be considered a generic concept then there are subsets which address information demands (or requirements) and information wants (or desires). There are individuals who can articulate demands and there are those who have a desire for information but are not able to specify what it is that they 'need'." For example, one cost estimator may say that he needs a price for facing bricks while another estimator with the same objective may say that that he needs to prepare an estimate for tender purposes. The first person has stated a specific requirement and the second has expressed a desire for a tender bid. This suggests that there is a requirement to separate out these two aspects in order that the relevant information may be identified, for it remains unclear as to what extent those who require information can articulate their demands and to what extent they have become conditioned in their demands by their experiential bases. It is perhaps a consequence of the failure to do this that a situation has arisen in which there is no consistent identification of relevant criteria among even leading researchers, consider Skinner (1979), Paterson (1977), Fine (1968), Bennett (1969), Bishop (1966), Ferry (1967).

Brittain (1970) helps to chart the semantic jungle. "Information Demands refers to the demands which may be vocal or written and made to an information system. Information Wants is more difficult to define. In some cases wants will be synonymous with demands. For example a user may know that information relevant to his work is available and makes a demand to an information source. At the other extreme is the individual who makes very few demands but has many needs." It may well be that estimators and quantity surveyors may be unaware of the availability of information to satisfy their needs or may assume its unavailability, thus may not consider it relevant.

Faibisoff and Ely (1976) state "This person may have a felt but unexpressed need (perhaps because of inertia or because he does not have sufficient specific details about the need to translate it into a demand), or he may have an unfelt need (in which case he may not be aware of it until this is pointed out, at which time he may readily agree he has a need). Parker and Paisley's (1966) conclusion regarding problems of identifying information needs is useful: 'Real needs may go unexpressed if users consider them to be unrealistic (i.e. not capable of




EXISTING SITUATION




IDEAL SITUATION

Information Needs and Requirements

Figure 10.

being realised by existing systems.' This has previously been confirmed in the work of Hardcastle (1978) in regard to the attitude of Quantity Surveyors and Estimators to the establishment of a revised Standard Method of Measurement and in the general resistance to change.

Taylor (1968) identifies four points along the need continuum:
1) an actual but unexpressed need (visceral);
2) a conscious description of the need;
3) a formal statement of the need and
4) a compromised need.

Considering the previous Shannon model (1949);

$$(3) \qquad I = S(Q/X) - S(Q/X^1)$$

where Q is the well defined question, I is information and X is knowledge,

and the associated model;

$$(4) \qquad E_{acc1} > E_{acc2} = f(I_1^2)$$

it is clear that the well defined question (a need expressed as a demand) is important in achieving a change in the observers knowledge and consequently his uncertainty. An ill defined question may well result in the reduction of some uncertainty but not necessarily the optimum reduction. It is the relevant question which should be asked.

It is considered that the essential problem of provision of relevant information at each of the iterative stages is that which results from the separation of the design and construction process (see later), i.e. the problem is one of 'communication' of information as evinced in the need for communication documents, i.e. drawings, specifications and bills of quantities.

While considering the nature of information it should be taken into account that the term 'information' is often understood to mean different things; it is therefore necessary in scientific research into the nature of information to state precisely how the term is being used.

Although the transfer of the grade of organisation is often called 'information transfer' in the sense of 'information' being carried along the path of the communication chain (Klaus 1976), it is not immediately clear what 'information' really means.

In a study of 39 definitions of Information Science, Welisch (1972), found only eight definitions of information: "All the rest couched unashamedly in circular definitions, which would be thrown out in an introductory course on logic at the undergraduate level, followed the pattern "information science investigates information"... even the eight valiant definers of information...do not... arrive at an agreed upon definition, nor do the definitions have any common element".

Webster's Dictionary states that 'information may be news, data, fact, intelligence or knowledge'. "The public is not concerned that fact, data and news are not necessarily synonymous. All that matters is that 'something has been acquired that one did not have before. Information theory treats this something as that which is the opposite of uncertainty", (Faibisoff and Ely 1976). Faibisoff and Ely (1976) also state that "Information is a symbol or set of symbols which has the potential for meaning", "It is that which reduces uncertainty. It is that which assists in decision making." "... sources have to be considered simply as raw data until they are used to resolve uncertainties."

Costello Jr. (1965) confirms the view that data is different from information and states that "Data can be numerically expressed, that is quantified, quantifiable, tabular or objective...Data is highly repetitive. Information is not highly repetitive or quantified or quantifiable; it is characterised as narrative, subjective, qualitative, textual or descriptive. Data, then, are numbers or unit facts, frequently repeated, whereas information is ideas".

Information is used in Roget in at least seven diverse senses; and, when considering synonyms, there are over 100 associated words. In Shannon's information theory, information is restricted to the context of signals, information is very specifically defined as a property of a collection of coded signals or messages which reduce the receivers uncertainty about which message is sent. Thus treating only the technical problems of communication and creating a limited view of information.

Yovitz and Ernst (1967) define information as a data of value in decision making. In its most familiar sense today however, information is news, intelligence, facts and ideas that are acquired and passed on as knowledge. Ursul (1970 ) wrote in 1970 that information expresses a property of matter inherent to all spheres of matter, and this reflects the interpretation of the word which was used in medieval times with a more active constructive meaning; as something which gives a certain form or character to matter, or to the mind; a force which shapes conduct, trains, instructs, inspires or guides such that any product of nature could be considered as matter, energy and information. For example, it may be said that the mechanical, physical and cost performance of a cavity brick wall is a function of the inputs of matter, energy and information and how these inputs are co-ordinated.

In order to be not mistaken in using the term 'information' care must be taken to differentiate between information and information process and to identify precisely whether 'information' is to be understood as a process involving information or as a product or the contents of such a process, that is as a phenomenon relatively at rest.

However, information as a product or the contents of a process involving information is a result of and is dependent on such a process.

The definition of information is not easy and it is no surprise that many researchers in construction economics have not tackled the problem of definition.

An attempt to comprehensively distinguish between process and product has been made by Leupolt (1978) who perceives that the general information process is a process in which the active grade of organisation of objects and phenomena or their *systems* purposively acts on some other objects and phenomena or their systems. Thus the information process can be characterised by the following:

"1. The grade of organisation of objects and phenomena is mapped as 'grade of organisation'; this means that it has been related (coded, stored) in a more or less stable way to some symbol or system of symbols realised by means of a carrier with an implied meaning and a pragmatic tendency influenced by the conditions and demands of the higher level total system or the surroundings of the involved objects and phenomena". This statement can be related directly to the influence of the Standard Method of Measurement within the process of design and construction. It may be argued, however, that the 'conditions and demands of the higher level total system' which have influenced the 'implied meaning and pragmatic tendency' of the SMM based Bill of Quantities have historically been those that were defined in an environment of a trade based industry with consistent contract procedures, Skinner (1979). The attempts to change the document up to the present day being in response to changing conditions and demands at the higher level.

"2. The effect is carried as potential information (this means that the effect can be realised with some probability as 'information' and transmitted as the contents of some communication chain".

"3. The effect is being conducted, transferred to an object or phenomenon 'receiver' for communicating with it *through* the channel".

"4. The effect is at first received by the object or phenomenon 'receiver' in its exterior symbol shape".

"5. The grade of organisation of the source objects and source phenomena is immediately or somewhat later reflected, decoded and reproduced by the receiver object or receiver phenomenon as the semantics involved, the uncertainty of the source object or source phenomenon being 'wholly' or partly overcome, deleted in the receiver".

"6. The reflected grade of organisation makes its pragmatics to be exploited or applied by the receiver object or phenomenon; this means that the structural and functional mode of existence of the receiver (user) has been altered".

Some aspects of the above information processes will allow the following different interpretations of 'information'.

"1. Information is the semantics of a message: this means the grade of organisation has been mapped by a source more or less adequately transferred to, and reproduced by a receiver".

"2. Information is the symbol (always material) or the system of symbols (the sigmatics of a message), being the grade of the grade of organisation to be transferred".

"3. Information is a unity (=news) of the semantics and sigmatics of a message".

"4. Information is the syntax (syntactics) of the symbols or systems of symbols (sigmatics), by means of which a statistic account (probability, chance) of some events can be given".

"5. Information is 'property of properties' (higher predicate) of some real objects, phenomena and processes or their systems, transferring some grade of organisation (property of some real processes where processes-property of matter)".

"6. Information is the process of transferring some grade of organisation (in an active way: to inform somebody or oneself; in a passive way: to be informed)".

"7. Information is the contents of a connection between interacting systems, the constantly changing states of these systems and of the channel used".

"8. Information is transmitting a 'grade of organisation' in order to control a potential receiver in a predetermined way".

"9. Information is receiving a 'grade of organisation' in order to reflect, to cognize, some situations and the grade of organisation of a potential source".

"10. Information is the 'grade of organisation' received, (semantics) that posses some news value for the receiver".

"11. Information is the 'grade of organisation' (semantics) that possess some utility value for the receiver".

The above mentioned versions in applying the term 'information' demonstrate that:

1. Information is not a uniquely determined phenomenon.
2. Information is a phenomenon that is closely tied up in some way or other with the transfer of 'grade of organisation'.

The latter statement reflects the concept of reducing uncertainty by improving knowledge through the transfer of grade of organisation.

As above Leupolt (1978) defines information "as that grade of organisation of a (receiving) system that is generated under certain conditions as a result of transferring a grade of organisation from another (source) system. Information is defined as the product of an information process existing in some forms and kinds and featuring aspects such as semiotic aspects and aspects of reflection and control".

In defining the nature of information it is also necessary to explain all processes involving information in a single manner. Though Leupolt (1978) has attempted to do this it can only be done in a consistent manner by taking the dialectical materialist propositions interpreting the world in a unified way and deducing therefrom information problems (see later model).

From the fact accepted by dialectical materialism that the world is a unity of matter, it follows that all real objects, phenomena and processes are related to each other directly or indirectly and are mutually dependent. The importance of contract documentation within communication is to be found in the ability of the documents to reflect the unity of matter by conveying information which transfers a 'grade of organisation' from the design teams conceptualisation to the contractors process of estimating, planning and control and similarly by the feedback process to the quantity surveyors process of cost estimating.

There are a number of factors which contribute to the communication process and therefore to the transfer of 'grade of organisation' to the estimating activity. Thus the specific importance of these factors cannot as yet be determined because of the absence of a suitable model. However, the results of the transfer process have been noted by many researchers (see Chapter 1), and the conclusion must be that the 'grade of organisation' transferred from design team to construction team is less than that from the construction team to the design team, (consider the work of Morrison and Stevens 1981).

"All real objects, phenomena and processes and real interdependencies involved are based on motion. Although every motion and process are controlled by substance (mass or material) and energy, the concrete interdependencies between distinct objects and phenomena are not only determined by these *controlling components, but in decisive measure* by the grade of organisation (unity of structure and function) of the objects and phenomena involved", (Schutz 1970).

In the broadest sense every stimulus offers the potential of providing information but a more manageable way to look at information is to consider it as symbolic representations of reality, words, spoken and written, graphics, pictures, numerals and combinations of all these. A basic test however is its capability to reduce uncertainty. Here, the work of Skitmore (1985) should be noted in the distinction between early stage cost estimating and later stage cost estimating and the apparent lack of impact upon accuracy as a consequence of the associated increase in quantity of 'information'. "A comprehensive review of the general accuracy expected for these two types of estimates has been carried out by Ashworth and Skitmore (1982, 1985) indicating a standard deviation of 15 to 20% to be appropriate for conceptual estimates reducing to 13 to 18% for detailed estimates". Jupp and McMillan (1981) noted that estimating accuracy improved only slightly with the increasing number of previous bills used, with no improvement being observed with the use of more than three bills. Skitmore (1985) also found the use of past contracts information to have no significant effect on accuracy levels. "The provision of current project information produced an increase in average estimate levels from -5.63 per cent error (18.28 standard deviation) to 11.13 per cent error (14.59 standard deviation) with all sixteen pieces of information. In moving between the two types of estimate, Morrison and Stevens (1981) found a change in mean deviation from 19.23% to 18.48%". Similarly in another experiment Skitmore (1987) notes "only a very small amount of information was used by the most expert surveyors for relatively very accurate estimates"

## 4.2 Communication

Several disciplines ( particularly psychology, communication theory and information science) have become increasingly concerned with the manner in which humans gather, store and communicate information.

The Oxford English Dictionary gives twelve different definitions of the word communication. The most common use is when we take it to mean imparting, conveying, exchanging ideas or knowledge or any kind of information by means of signs and symbols.

This view is confirmed by Faibisoff and Ely (1976) who argue that communication of knowledge is more than simply communication of data, "Communication may be operationally defined as the transfer of meaning." This is seen as a dynamic process with an established communication-information interface which within design and construction is performed by the drawings, specifications and/or bill of quantities.

However, such interfaces must be considered within a particular performance environment. Meltzer (1971), notes, "Merely spreading data around in various formats through a multiplicity of media does not guarantee the reception and comprehension of information itself. For communication an exchange of meaning must occur...there must be an understanding of the data"

Leupolt (1978) notes that, "The effect of the grade of organisation can be eventually expressed as an interfering process between some objects (and active persons)". These relations may be termed "communication relations (or communications)...".

Thus according to Leupolt's interpretation 'communication' can be understood in the following way:

1. "Some concrete objects being connected in a relatively stable way, resulting from the mutual transfer of the grade of organisation and associating them to a higher level system".
2. The transference of the grade of organisation being a process leading to the result under point 1. being repeated continuously".

Communication relations (communications) therefore arise from the effect of the grade of organisation being transferred from at least one object (source, transmitter) to at least one other object (receiver).

It is well to note at this stage the definition of knowledge given by Bell (1973), "knowledge is a set of organised statements of facts or ideas, presenting a reasoned judgement or an experimental result, which is transmitted to others through some communication medium in some systematic form".

Knowledge and information are not the only aspects that create a resolve and instil wisdom, but they are important aspects.

But communication of information only takes place within the context of a specific process and is a direct function of the experience base of the receiver and his associated knowledge base (Schutz 1970).

In relation to the above statements it is clear that design documentation, even in its most crude form of an outline brief or sketch contains knowledge which once given form becomes a communication medium. The success of this communication medium is the area for investigation in this thesis, see later.

Furthermore, it is understood that communication of knowledge is effective when and if information that is transmitted from one file results in changes in another (Shannon 1949). Accepting this statement and relating to studies of estimating accuracy carried out by Morrison and Stevens (1981), Skitmore (1985/87) and others it would seem that the provision of further data in the design process does not necessarily result in significant improvements in accuracy thus indicating that what is supplied remains substantially data and not information or indeed significant.

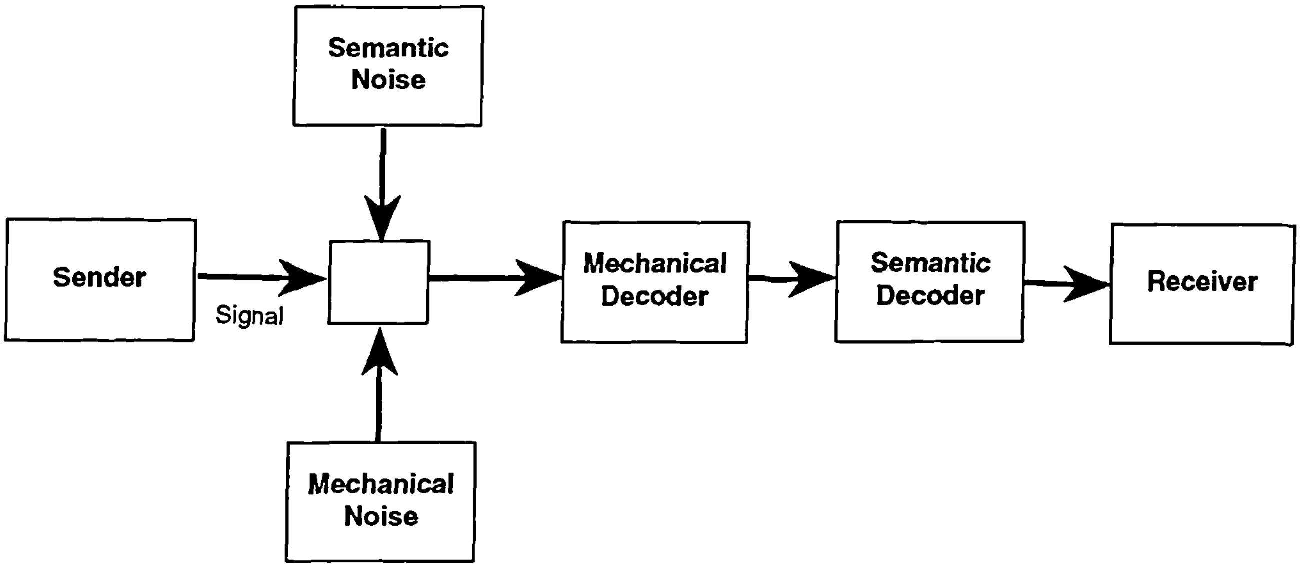
This thus gives a guide as to how to proceed, for the quality of information and the effective communication of knowledge may be judged by the changes which are effected in those functions which are the receptors of the information. However, care must be taken here, for the receptors sedimentation of knowledge (Schutz 1970), which contributes to his experiential base (Skitmore 1985) is also crucially important in determining whether communication of information is effective.

The ability to communicate purposively depends on an ability to use and control the media of communication, be it a drawing, specification or bill of quantities. Communication necessarily involves the sending of messages and in the sending of messages by whatever means the situation involves a source, e.g. the client objectives, a transmitter, e.g. the client design team and in particular the client quantity surveyor, a channel, e.g. the bill of quantities, a receiver, e.g. the contractor, and a destination, e.g. the estimating, production processes. In the 'Mathematical Theory of Communication', by Shannon and Weaver (1945) it is diagrammed as shown in Figure 6.

As noted in Chapter 2 before he can communicate with B, A has first to sort the relevant information and order it into a 'message' which is an ordered selection from an agreed set of *signs put together for the purpose of communicating* information. When this done, A has then to encode the message in a physical form, a 'signal', or bill of quantities description. This signal is then transmitted through a 'channel', i.e. the bill of quantities. On receiving this signal, B will then decode it, e.g. into resource, time and finance entities. As the message passes from source to destination and through the processes of encoding and decoding, it may become distorted. It follows then that any theory or practice which causes the loss of data elements, either through their mis-representation or by restricting their flow must be considered inadequate. As identified earlier such distortions are referred to as 'noise'. One might here quote the work of Fine (1968) in regard to the allocation of bill items to cost centres and the confusion which arose from the allocation of these items to an increasing number of cost centres.

In 'Power of Words' Chase (1954) adapts the Shannon and Weaver model as shown in Figure 11. Two types of noise occur, mechanical noise and semantic noise. That which will concern this research is semantic noise which refers to any kind of alteration which is made to the message as sent, by the fallibility of the 'medium' of communication, e.g. language, set of rules or principles. Typically noise occurs in the communication media of construction as a consequence of incomplete design information, mis-representation of design information (provided or not), errors in measurement and item description, and aggregation of data resulting in loss of specificity. Thus information contained in the bill of quantities can be taken as

(13) $$I_1^2 = ([(f_1^2 \text{ form})(1-M][1-D] + k_1^2) - R$$

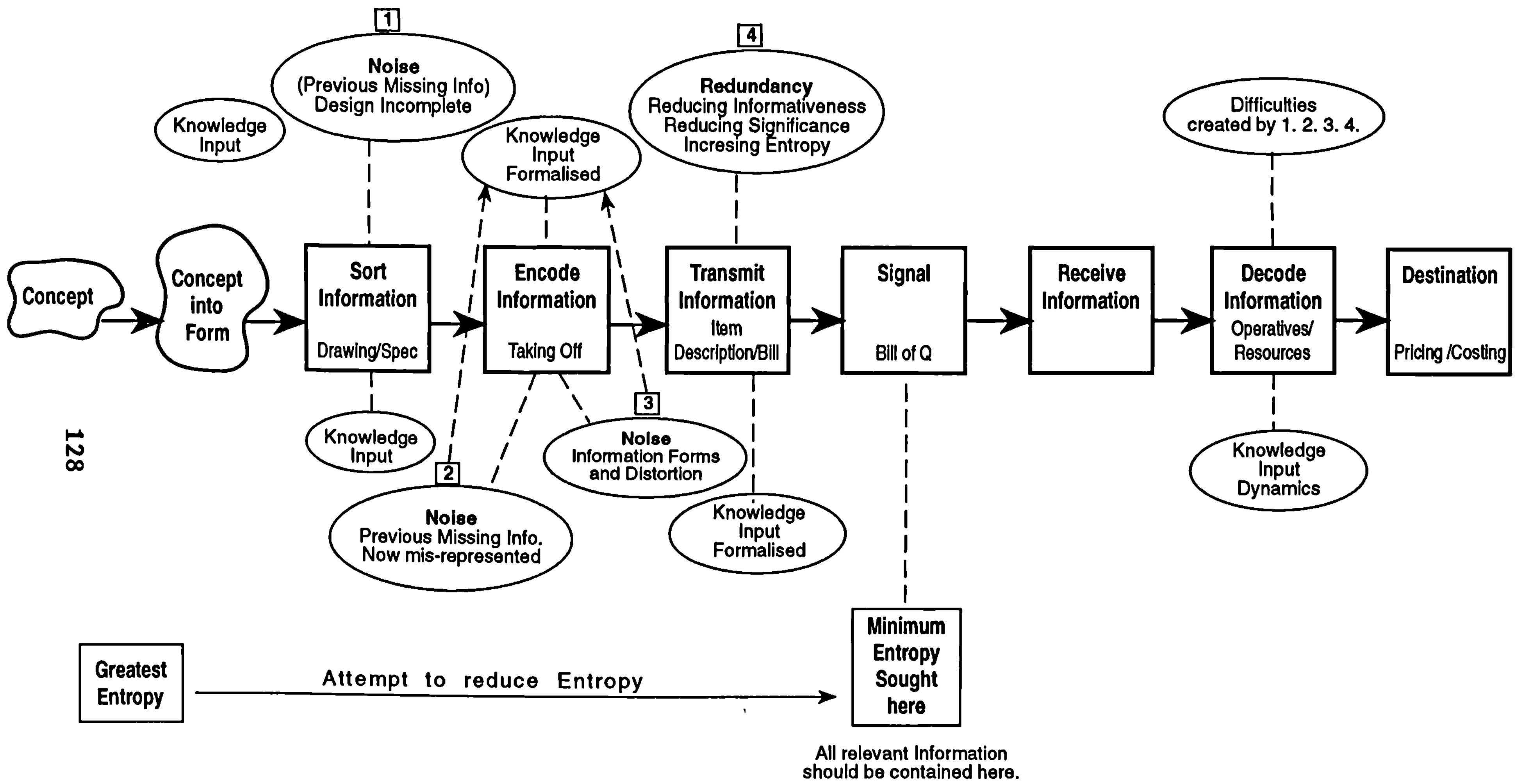



**Chase Communication Model**

Figure 11.

Semantics is the materialised expression of the grade of organisation to be transferred by means of information transfer processes and represents potential information in the channel and real information with the receiver, (see Figure 12 Secondary Model).

The information transfer process in the construction industry is normally realised in a documental way but can similarly be realised in a non documental (oral) way. Again in this work the concentration is on the documental approach. This process can be interrupted at some phase in the channel and suspended and restated and brought to an end at some later time. Further, and this is the usual case in construction, the documental shape of an information transfer process can - without having come to an end in itself - become the starting point for a new information




Secondary Model

Figure 12.

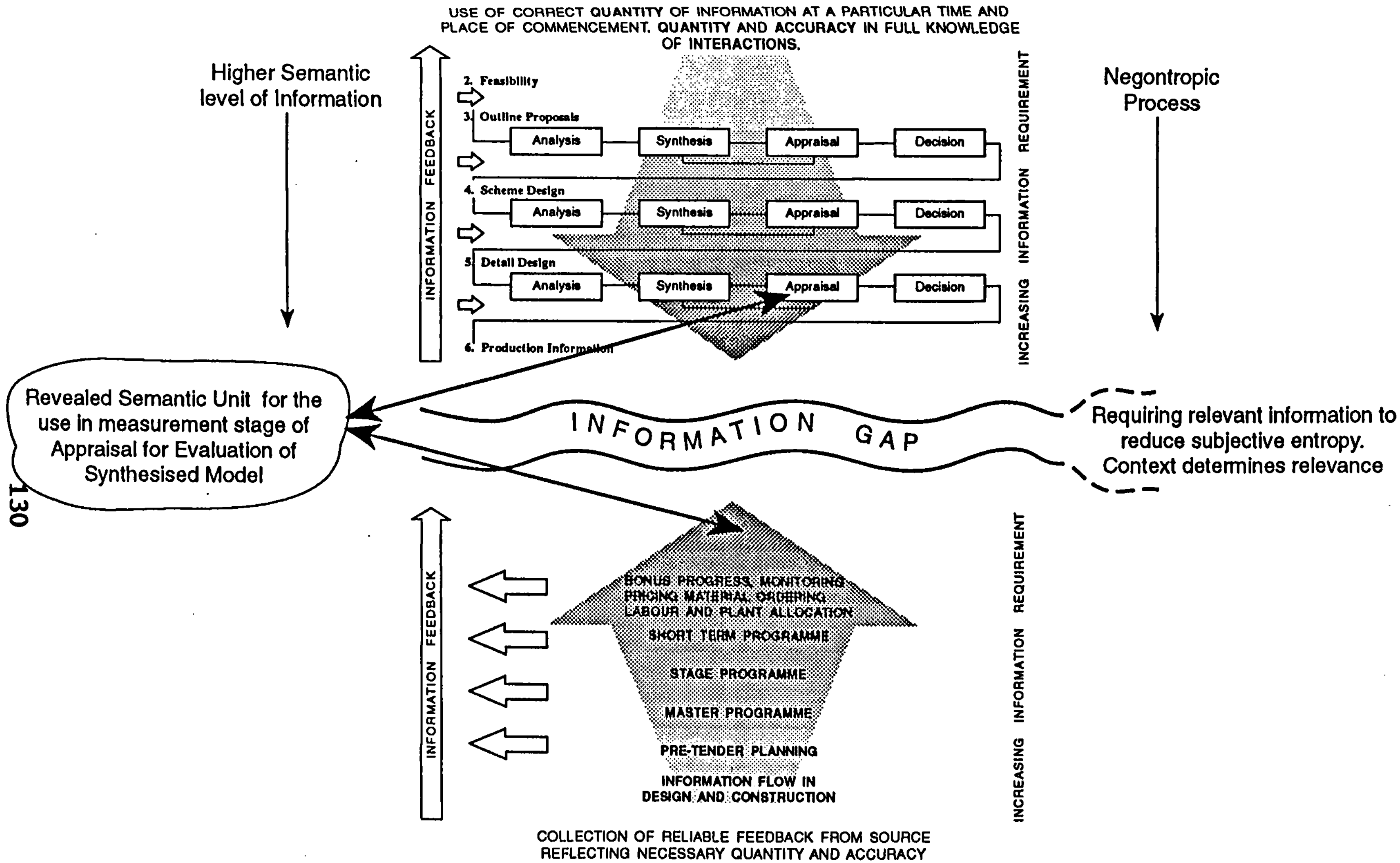
process taking place via a corresponding receiver who acts simultaneously as a source.

When an information transfer process realised in documental or non documental form is the starting point for a new information process, the latter takes place on a newer (higher) semantic level or stage and aims at conducting the original information transfer process to an end.

Here one may consider how information evolves during the design of a building and is formalised with regard to the RIBA plan of work, (see Figure 13).

It is the task of both information processing and information transformation to reveal semantic units offered in documents in such a way that objective situations become visible and accessible to certain users and may be used to resolve uncertainties. Thus it is essential to information transformation and processing operations in construction that the semantic units utilised, whether they be words, phrases, physical measure, work sections or specifications are accessible and contribute to the performance of those tasks which form the context for the information transfer. They must contain 'relevant information'. They must also be readable.

In the application of the above diagrams and concepts to construction the following should be noted;




**Semantic Level of Information**

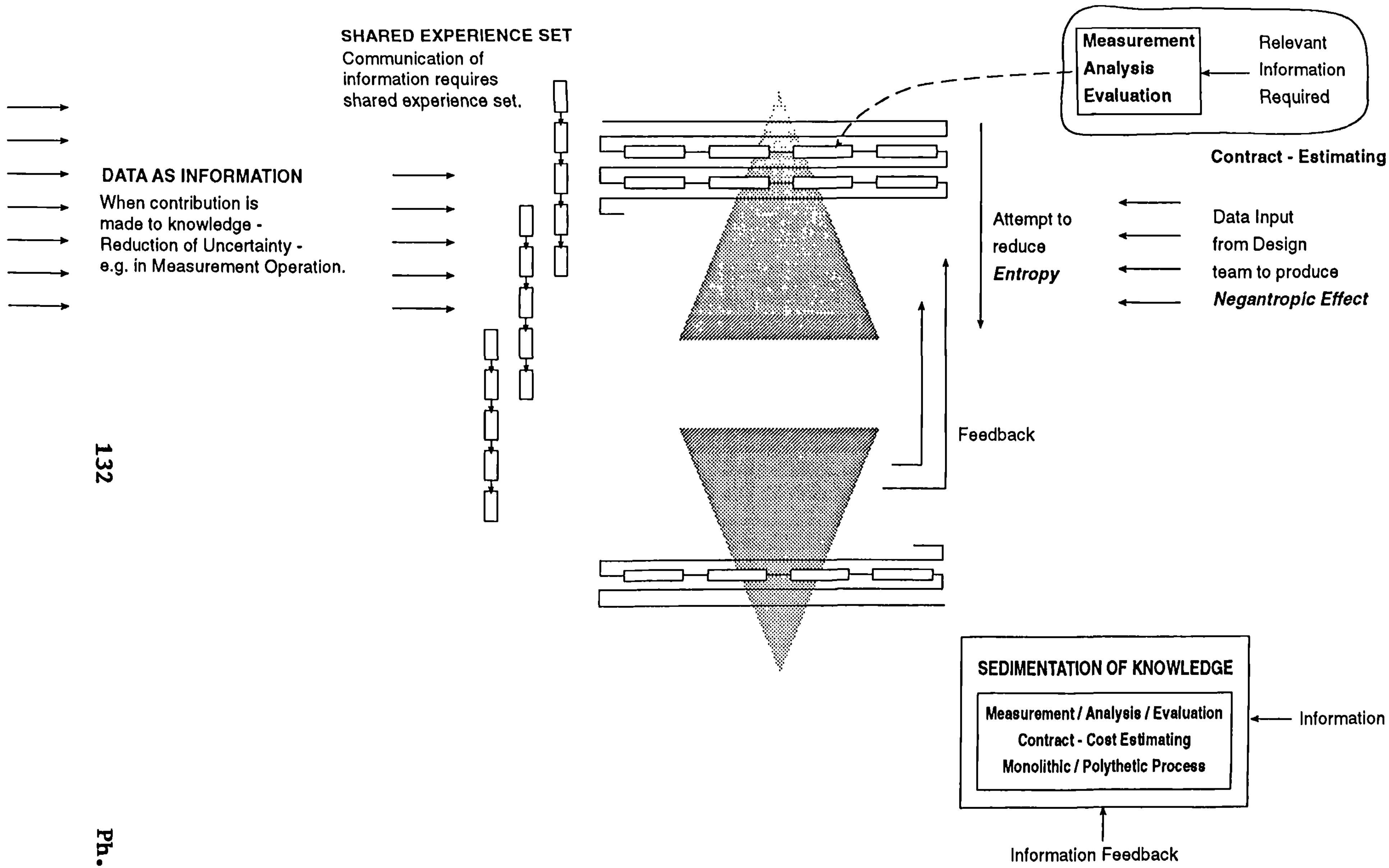
**Figure 13.**

1. the importance of feedback and use of historical information in subsequent communication,

2. the fact that noise affects all parts of the process,

3. the fact that messages set up a relationship between sender and receiver.

The entire communication process is concerned with the relationship which is set up between sender and receiver, i.e., that between the contracting team and the design team and their perceived objectives. Further, an essential fact to be grasped is that in order to communicate information of any sort the message has not only to be received but also understood. Effective communication between the sender and the receiver results only when they share experience, i.e. the intersection of their experience set is non-empty. An experience set is an ordered set of data elements and relations. Note, therefore, that an experience set can be a document. In general, sender and receiver communicate when their experience set is transformed into an interface experience set. As an example consider the communication between the design team and the contractor; the interface experience set is the contract documentation. In the case of documentation, this means that the receiver must have some prior knowledge of the organisation and representation of the data elements in the document in order that he might distinguish the relevant data. A crucial point is however, is that this distinguishing operation depends on how the data is organised for it is this organisation and




Tertiary Model
Figure 14.

the relevance of the data which will provide for effective communication, (see Figure 14 Tertiary Model).

A central problem of communication is the problem of meaning. It is vital to remember that when one communicates one sends messages to someone about something and for some purpose. The receiver assumes that no information is being communicated if no recognisable patterns are being received and these patterns will not be recognisable if the pattern does not reflect the receivers experience set, and can be linked with his sedimentation of knowledge. This raises a problem, for how can one improve the communication process if one is restricted by the receivers current experience and thus his perception of what is relevant and what is needed? (Schutz 1970), (Brittain 1970), (Faibisoff & Ely 1976). This is posited as having a causal relationship with the fact noted by Ogunlana and Thorpe (1987) that many cost models developed as a consequence of research have not been adopted by professionals in the industry.

In the field of construction and in particular construction cost estimating, it is highly unlikely that the 'pattern' of contract documentation will not be 'recognisable', but the extent to which it is recognisable will vary among documentation as a consequence of the proclivities of the 'encoders', the quantity and quality of information they are in receipt of and the quality, experience and ability of the receivers. This aspect of 'pattern' is to be investigated in this thesis as is the effect of 'pattern' variation on estimating.

## 4.3 Informativeness

Distinguishing information (in the traditional sense) in a message is seen as essentially a problem of selection. Of the letters, words or images being sent to the brain, but what determine which are meaningful, or separates information from noise?

It is acceptable common usage to speak of some sentences or propositions as being more informative than others, or perhaps conveying more information. One may speak of a sentence or proposition being more informative to a person today than it was yesterday. It is also not unusual to speak of the information conveyed by a sentence or proposition as well as the information it conveys about a certain subject matter. In all these usages of the word 'informativeness' and 'information', there is denoted a property of sentences or propositions. Whether or not they denote the same property in all such usages may not be clear, it is nevertheless clear that there is a well established and intuitively acceptable usage of 'informativeness' to denote some property or properties of sentences or propositions. The aspect of informativeness is investigated here with regard to specific words, word combinations and item descriptions.

It has been suggested that statistical information theory is not directly concerned with any concept of information involved in these usages (Sneed 1967). In most authoritative expositions of statistical information theory, some care is taken to explain that the engineering problems of efficient communication are treated independently of the informativeness, in any sense involved in the usage exemplified above, of the messages transmitted. Despite these disclaimers, it appears that the distinction between the concept of information employed in statistical information theory and the concept of information as a property of propositions is not always strictly observed and some have seen a need to reiterate this distinction (Bar-Hillel 1955)

In considering the informativeness of propositions it is customary to distinguish two kinds of informativeness - semantic and pragmatic (Bar-Hillel 1964), "A semantic property of a proposition is one which a proposition possesses in virtue of what must be the case for it to be true - its truth conditions. thus one should be expect to be able to determine whether a proposition is semantically informative or semantically more informative than another, by examining only the truth conditions of the proposition". In the context of construction cost estimating this can lead to very interesting philosophical and accounting discussions about the validity or truth of price data and its basis in reality, however this will not be pursued here and the reader is recommended to view the work of Brown and Jacques (1964) and Skoyles (1977).

In particular one should not have to consider whether anyone knows or believes the proposition to be true, or whether believing or knowing that it is true might be useful to anyone. In contrast, a property is pragmatic if a proposition has it in virtue of certain properties possessed by people who have certain attitudes, such as belief and desire, toward the proposition. An example is a property which a proposition has in virtue of the usefulness to some individual of knowing or believing that the proposition is true. Thus in determining whether a proposition is pragmatically informative, one should expect to consider more than just the truth conditions of the proposition (though these might be relevant too). Things like beliefs, desires and capabilities of people - their attitudes towards other propositions - as well as their attitude to the proposition in question might be relevant too, e.g. whether the contractor's estimator or the client quantity surveyor is attempting to cost resources or simply price the bill of quantities to obtain the contract, his view of market conditions, his experience base and understanding of the work involved.

It is hypothesised here that while a bill of quantities is perceived as being pragmatically true, it is in many situations semantically untrue as a consequence of data loss and data misrepresentation, i.e. as a consequence of noise (Chase 1954).

There is a significant body of literature beginning with the work of Bar-Hillel and Carnap (1955, 1964), which undertakes to distinguish and explicate various senses of semantic information and semantic informativeness (Hintikka 1968). In this work a mathematical formalism very similar to the formalism employed in statistical communication theory plays a leading role. Even though the concept of information being explicated is explicitly recognised as being distinct from the communication engineer's concept. One is tempted by the similarity of formalism to say that the same concepts are applicable in explicating both concepts of information. In particular one might be tempted to say that the concept of entropy is crucial in understanding both concepts of information. There has been no systematic effort directed toward developing a comprehensive theory of pragmatic informativeness. However, much of the work done by statisticians concerned with the design of experiments can be viewed as attempting to provide a partial account of the notion of pragmatic informativeness. They are concerned with expounding principles for ranking various questions one might ask in accordance with their pragmatic informativeness (Savage 1954). In this effort, attempts have also been made to apply the mathematical formalism of statistical information theory, most notably by Lindley (1956), who suggest that the informativeness value C, relative to a specific question Qx is proportional to the expected value of the change in the agent's entropy of knowledge X when he discovers which member of C is true. Roughly, more informative C's are those expected to produce a greater change in the agents entropy. The link with the previous work of Shannon (1949) is clear.

# CHAPTER 5

# KNOWLEDGE, INFORMATION AND EXPERIENCE

## 5.1 Knowledge Accumulation

It has been noted by Einhorn (1982) that information without a knowledge of task structure cannot provide a contribution to knowledge accumulation.

Communication of knowledge and information systems can be considered by themselves but they do not exist in a vacuum. They operate within, by means of, and under constraints imposed by their environment. They affect and are affected by the environment. The same knowledge communication process, the same information system, can be related to a number of realities of an environment, to a number of environments and can perform many functions, (Saracevic 1975).

Knowledge, information, communication, information systems - all are embedded in, all reflect some system of human values - ethical, social, philosophical, political, religious and/or legal values. Therefore when considering relevance, one may also involve aspects of the environments, realities and values.

If an attempt is to be made to identify the success and failures of the current approaches to communication of information for cost estimating in the design and construction

processes then it is essential to consider how knowledge is accumulated and utilised and as a consequence extend the technical tertiary model previously developed to take account of knowledge aquisition and utilisation.
Skitmore (1985) notes the importance of 'experience' to an estimators ability to estimate future costs of construction and Flanagan and Norman (1973) note the importance of familiarity with project type as do Morrison and Stevens (1981) yet no clear philosophical argument is postulated in regard to what constitutes 'experience' or what it is about experience that produces improvement in estimating accuracy.

If one is attempting to model the communication process in order to propose improvement in information transfer, then it is necessary to attempt to understand the components and interaction of knowledge acquisition, retention and utilisation.

Saracevic (1975) states that, "In information science, the connotation of communication and information is extended to, and limited to, the context of knowledge as used in the theory of knowledge."

Schutz (1970) notes that knowledge means not only explicit, clarified, well formulated insight, but also all forms of opinion and acceptance relating to a state of affairs as taken for granted. When conventions exist and principles are accepted as in the case of formalised contract documentation then it may be postulated that this documentation forms the framework for knowledge 'as taken for granted' and as such conditions the formulation of the 'question' which seeks information. Whether this is 'well defined' as understood by Shannon (1949) is as yet unclear. For the well defined question must reflect the needs of process (estimating) and where the 'as taken for granted' documentation leads to an incorrect formulation of the question, 'wants' may be expressed in the question but not 'needs'.

When;

(3) $$I = S(Q/X) - S(Q/X^1)$$

where Q is the well defined question, I is information and X is knowledge and knowledge contained in the bill of quantities can be taken as

(13) $$I_1^2 = ([(f_1^2 \text{ form})(1-M)][1-D] + k_1^2) - R$$

and the associated model is;

(4) $$E_{acc1} > E_{acc2} = f(I_1^2)$$

Then a significant change from $E_{acc1} > E_{acc2}$ will only take place when Q is a well defined question which is reflective of the needs of the estimating process.

(14) $I_1^2 = Q/([(f_1^2 \text{ form})(1-M)][1-D] + k_1^2 - R$

Ogunlana (1989) notes that the opinions a person holds in regard to events, activities or situations depends on "(a) how information about the event/activity is encountered, (b) how information encountered is treated, (c) how processed information is stored, (d) how stored information is retrieved from memory, (e) how information retrieved from memory is processed prior to its application, and (f) how the processed information is used".

It has been argued that there are two ways in which the mind may grasp the meaning of its own previous experiences. All of them are built up step by step, phase by phase, in processes of inner time - "polythetically" as Husserl (1983) states . "I may in the reflective attitude reconstruct this polythetic building up of the meaning of my experience upon which I now direct my reflective glance". The polythetic process of building up of the meaning of an experience may be reconstructed in memory and all the steps run through by which the meaning of the experience became constituted. Schutz (1970) argues that one must choose this procedure "if the meaning of the experience in question consists exclusively in the polythetic arrangements of elements in inner time, as it is the case in music and poetry and other forms of so called time-immanent objects. I can reproduce the meaning of a work of music merely by reproducing its flux (at least mentally) from the first bar to the last"; "I may render the 'content' of a poem in one or two sentences, .... Yet, in order to grasp the meaning of the poem as such, I have to read or recite it, at least mentally-and that is to reconstruct polythetically the many articulated (i.e. polythetic) steps in which its meaning has been constitute".

Apart from these cases of time-immanent objects, however, and especially with respect to experiences which are conceptually formulated by a process of ratiocination. It is possible to grasp in a single ray - monothetically, as Husserl (1983) calls it - the meaning which has been built up polythetically. In this case, an habitual possession of knowledge consists in the experienced meaning as monothetically grasped.

It has been noted in the cognitive model postulated by Hammond (1981) that there are three task types, analytical tasks, intuitive tasks and semi-rational tasks. Ogunlana (1989) argues that cost estimating is a semi-rational task. Ogunlana also argues that "a tender estimate is more analytical than a budget estimate", however no evidence is provided for this statement and the approach of Hammond (1981) does not preclude intuition playing a major part in exercises in in which there is apparent but ineffective analysis.

The distinction between early stage cost estimating and later stage cost estimating and the apparent lack of substantive impact upon accuracy as a consequence of the associated increase in quantity of 'information' has been noted by a number of researchers. Skitmore (1987) notes "A comprehensive review of the general accuracy expected for these two types of estimates has been carried out by Ashworth and Skitmore (1982, 1985) indicating a standard deviation of 15 to 20% to be appropriate for conceptual estimates reducing to 13 to 18% for detailed estimates". While experiments by Jupp and McMillan (1981) indicated that estimating accuracy improved only slightly with the increasing number of previous bills used, with no improvement being observed with the use of more than three bills. In a further experiment involving the "provision of increasing amounts of information" Skitmore found the use of past contracts information to have no significant effect on accuracy levels. "The provision of current project information produced an increase in average estimate levels from -5.63 per cent error (18.28 standard deviation) to 11.13 per cent error (14.59 standard deviation) with all sixteen pieces of information. In moving between the two types of estimate, Morrison and Stevens (1981) found a change in mean deviation from 19.23% to 18.48%". Similarly in another experiment Skitmore (1987) notes "only a very small amount of information was used by the most expert surveyors for relatively very accurate estimates"

The lack of definition of what constitutes 'information' in these experiments has been noted previously, however it may be posited that a further concept ignored in these studies is that of knowledge accumulation and interpretation. The results noted above may well be a reflection of the impact or lack of impact when an estimator moves from a monothetic to a polythetic approach. Whether this results from the 'expertise' of the estimator at the monothetic stage or from the lack of relevant information to support the polythetic process is not clear. What is clear is that the negentropic processes which seek to improve the quality of information in support of the polythetic activity of the mind is making little contribution to improving the outcome of the estimating activity. "The evidence of previous studies ... suggests that increasing design information results in increased accuracy but not substantially. The ability of the estimators themselves would seem to have an effect on the resulting accuracy levels", (Skitmore 1986). Also, Neil (1978) notes "The human mind cannot collectively evaluate the 50 to 500 variables that may occur in a project to determine their combined effect. Yet it appears that most contractors, large and small use this approach in their bids". The preference for simple approaches to problem solving is demonstrated by Pohlman et al (1988) in a survey of large American firms which demonstrated a desire for simple cash flow forecasting models. "The additional effort required to implement the (complex) models are substantial and incapable of producing corresponding increase in model accuracy and reliability", (quoted in Ogunlana 1989). Further studies by the National Co-operative Transit Research and Development Program (1988) show that mass transit agencies in America prefer one or two variable cost allocation models to more complex models which are said to be too difficult and time consuming to apply.

One is left to consider whether or not the communication media used in construction for example, as a consequence of structure and configuration lends itself to the polythetic process at all, or whether because of inherent deficiencies, estimators revert to monothetic processes. Indeed, to what extent is the communication media reflective of the needs of the estimating process (monothetic or polythetic) and to what extent does it determine and condition the wants and demands of the estimators without adequately reflecting the needs of the process?

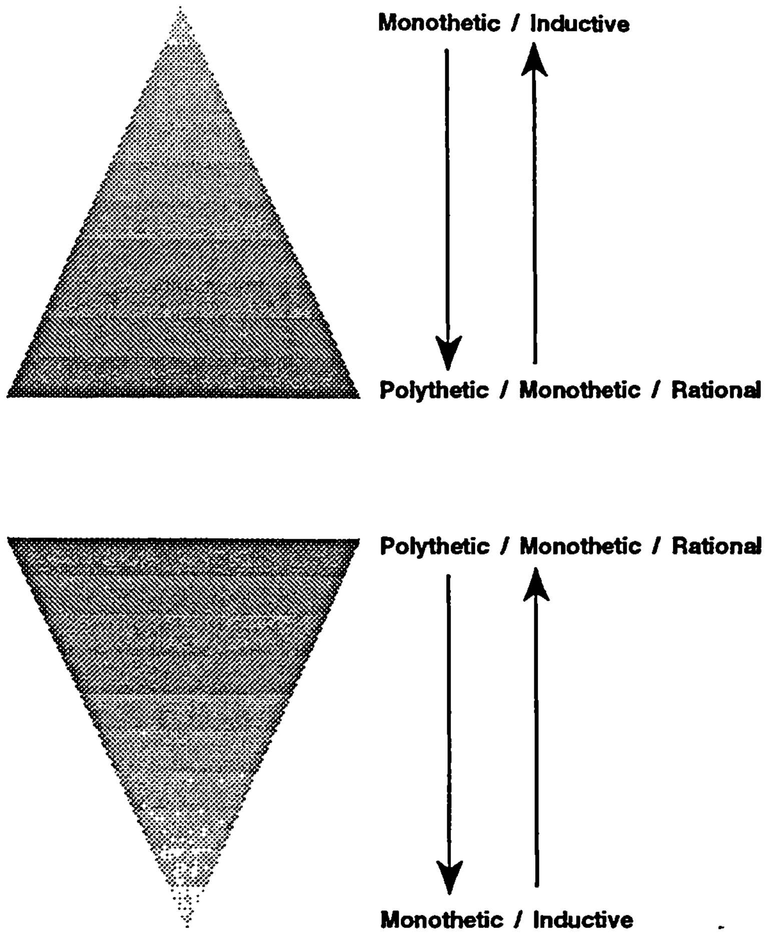
This is a crucial question for the clarity and distinctness of knowledge depends upon an ability to refer the monothetically grasped meaning of an element of knowledge to the polythetic steps by which such knowledge was acquired. The degree of plausibility of knowledge from conviction of empirical certainty to blind belief will be determinable according to how this knowledge was acquired by clear and distinct steps which can be polythetically reconstructed. As stated by Schutz (1970), "it depends on whether we can account for the source of knowledge by indicating the single acts of becoming aware, conceiving, understanding, apprehending, and learning by which we become cognizant of or acquainted with an element of our knowledge".

Important aspects of this process within the context of estimating must be the understanding and apprehension of the bill of quantity items and the resource costs which ultimately constitute the cost estimate. The ability of an estimator to take cognizance of these aspects must in part be determined by the documentation which communicates this information to him and the relationship of this documentation to the manner in which these resource costs were generated and recorded. To fail to make this contact is to fail to provide for understanding and apprehension. Comments made by investigators in this field suggest that this failure is occurring, (Walker 1974). Consequentially one is left to suggest that estimating even at the tender stage is to a large extent a monothetic process, (see Figure 15)

## 5.2 Monothetic/Polythetic Knowledge

It has been stated by Schutz (1970) that the distinction between topical and interpretational relevances is prehistorical for the monothetic grasping of the habitually possessed knowledge at hand. To look monothetically at the meaning of an experience suggests a shift in the configuration of systems of relevances prevailing at the time of its polythetic constitution. Then the topically relevant thematic kernel required bringing horizontal interpretational material into the centre of the field in a heuristic manner. At any step, the interpretational relevances, and therewith, the typicality of the approached object of an experience is modified, and all these processes are continued until the problem at hand is sufficiently clarified and solved. When this process comes to a standstill then the meaning-structure built up polythetically can be grasped monothetically.

The implication of the above statement is that one is drawing for one's monothetic interpretation upon a historical polythetic construction. This statement then has implications for the monothetic approach to estimating, for according to this interpretation, the success of the monothetic process and therefore the estimating process (certainly in the early stage estimates and possibly in later stage estimating), may well depend upon historical building up of an estimate from polythetic parts. The question must be then asked, to what extent is the experience of the estimator founded upon polythetic development and to what extent is it not? Indeed to what extent is it necessary for the estimator to acquire knowledge in this polythetic manner. Neil (1978) argues that "The human mind cannot collectively evaluate the 50 to 500 variables that may occur in a project to determine their combined effect", and Pohlman et al (1988) has noted that large American firms demonstrated a desire for simple cash flow




**Polythetic / Monothetic Processes in Design and Construction**
**Figure 15.**

forecasting models. "The additional effort required to implement the (complex) models are substantial and incapable of producing corresponding increase in model accuracy and reliability". Also, Ogunlana (1989) has noted that the National Co-operative Transit Research and Development Program (1988) show that mass transit agencies in America prefer one or two variable cost allocation models to more complex models which are said to be too difficult and time consuming to apply.

## 5.3 Knowledge Derivation

It has been noted that much of one's knowledge is socially derived and distributed. "Only a very small part of my stock of knowledge at hand originates in my own personal experience of things. By far the greater part is socially derived, originating in the experience of others, communicated to me by others, or handed down to me by my parents or my teachers or the teachers of my teachers" (Schutz 1970). The parallel can be seen here between the approach to the evolvement of an estimators experience and his approach to estimating. A situation is then created in which an estimators knowledge is derived from others and believed in various degrees of plausibility, becoming an habitual possession of things known i.e. "simply monothetically grasped without any attempt by me to perform any polythetic reconstruction of the steps leading to the monothetically grasped meaning" (Schutz 1970). A further related concept to note is that even if one attempted to break down socially derived knowledge into polythetic steps it may frequently turn out that "these traditional, habitual items of knowledge are such only as regards the monothetic meaning pertaining to the things supposedly known, whereas the tradition which contains the polythetic steps leading to this sedimentation (i.e. to the monothetic meaning) has been lost. It may even be that the polythetic steps were never performed" (Schutz 1970). Here we have a situation which is often reflected in estimating for one must question whether for example it has ever been possible using the current communication media to set up a situation in which a polythetic approach to estimating could take place given the historical context of its development as a trade based document for a trade based industry. Certainly, experienced commentators have in the past expressed severe doubts as to the utility of the media for estimating, Walker (1974), Bishop (1966), Hardcastle et al, (1978). Such approaches to knowledge acquisition then have a consequence in perceptions of what information is 'demanded' and what information is 'wanted', (see Chapter 4.1).

In the context of contractors cost estimating, while publications such as the CIOB Code of Estimating Practice may suggest the building up of an estimate from numerous discrete pieces of resource data, it has been suggested by some researchers that this approach may well be not be adopted (Crawshaw 1979). The alternative approaches noted by Crawshaw (1979) carry with them a greater sense of the 'polythetic' acquisition of knowledge as in an operational analysis one is able to take a heuristic approach toward those factors which create the resource costs, i.e. the operations and the associated material input. This contrasts with the approach of the Code of Estimating Practice where the calculation of values at the item level does not lend itself to a heuristic approach as a consequence of the lack of information (as feedback) which could be processed as relevant.

Within the context of cost estimating during design the quantity surveyor's difficulties of acquiring knowledge in a polythetic manner are compounded by the distance between himself and the manner in which the the costs are generated. While it may be argued that a quantity surveyor is still acquiring cost information in a polythetic manner, i.e. he can bring together the disparate relevancies of item descriptions to create a monothetic picture he remains unclear as to why these item descriptions are relevant. Indeed, given the confusion surrounding information demands and wants, the perception of what is relevant to the polythetic process may well be distorted. As Siegler (1975) states, "reasoning across different concepts is more homogeneous the less knowledge about the concepts is possessed by the individual".

## 5.4 Kernel of Meaning

There is no such thing as an isolated experience. Any experience is experience within a context. The first meaning-context of any experience is therefore that which connects it with past experiences and anticipated future ones.

James (1983) has noted that every word has a conceptual kernel of meaning which it designates, that is the meaning which can be found in dictionaries. Within a particular meaning-context this kernel is surrounded by a system of fringes of diverse sorts, for example relations connecting this word within a particular sentence in which it occurs with preceding and succeeding terms. Through these fringes the word has its particular meaning within the structure not only of the isolated sentence but within the whole context of speech to which this sentence belongs. Thus it is not possible to remove a word from its context and relations and expect to evaluate it. Though it is possible to identify these fringes from analysis of a word in context.

There are other fringes relating to the particular situation in which the term is used, to the situation of the speaker and listener, to the whole past of the stream of meditation within which a term occurs in the thought of a thinker reflecting by himself. Beyond these, there are fringes resulting from previous uses of the term in particular circumstances, emotional fringes provoked not by the conceptual character of the term but by its evocative incantation, fringes of association with words phonetically related and the like.

The net of fringes surrounding the conceptual kernel of meaning cannot arbitrarily be destroyed without annihilating the meaning context itself. While the meaning-context itself is sub-divisable it resists being treated atomistically, thus suggesting that it is essential to view communication media as a whole and to resist the temptation to dis-aggregate it. It is the actor and his function (in this context, estimating) which defines the state of affairs he wishes to bring about by means of his action, its outcome and result, and it is this goal or end which establishes the meaning-context for all the phases in which his ongoing action materialises itself. Living in his action he has only this projected goal and for this very reason he experiences all his acting as a meaningful unit.

## 5.5 Sedimentation of Knowledge

The study of the sedimentation of stock of knowledge has shown that it has many elements. Experiences show different degrees of clarity and various stages of plausibility, from the unquestioned acceptance in the form of blind belief, through the various forms of 'periodeusis', to the completed 'diexodos', or empirical certainty (Schutz 1970). Some of the experiences are grasped monothetically, while others can be referred to the polythetic steps in which they were built up; in view of this experiences have different degrees of distinctness. They are grouped into various more or less complicated meaning-contexts, dependent on the underlying "network of retentions and protentions, recollections and anticipations, the functional unity of our organism, the apparent coherence of the objects of the outer world, the fringes of the symbolic system to which they pertain, the unity of the project of our action and so on" Schutz (1970).

## 5.6 'Knowledge of' and 'Knowledge about'

James (1983) distinguishes two different kinds of knowledge, which he calls "knowledge of acquaintance" or "knowledge of", and "knowledge about". There are many things and relations about which a person may have a more or less vague and unclarified knowledge, but relatively few with which that person may be acquainted, through and through. This could be subdivided into the realm of things, events and relations about which a person may have knowledge into those states of affairs of which a person is merely aware, those of which he is conscious, and those of which he is informed.

To familiarise oneself sufficiently with things, events, relations, means to acquire an amount of knowledge adequate to carry out or to further a purpose at hand. This purpose may be a theoretical or practical one, and as such one's knowledge is always codetermined by a pragmatic motive (Scheler 1980).

In cost estimating the pragmatic motive has been identified by Ashworth and Skitmore (1982) as "a reasonably accurate calculation and assessment of the probable cost of carrying out defined work under known conditions ". This motive together with the manner in which the previous experiences were grasped (Husserl 1983) will dictate the information demanded but not necessarily the information which is needed.

When these things, events or relations become transformed from elements of knowledge <u>at</u> hand into those <u>in</u> hand they become artificialy isolated from their inner and outer horizons. Having the highest degree of familiarity, they do not need further interpretation or definition of their functional character. Having their fixed (i.e. routine) place in the habitually possessed means-ends relations and functioning as specific means for well circumscribed specific ends, they are more than typified, they are standardized and automized (Schutz 1970). They are the essential elements of the 'experienced' estimator. Their motivational relevances proper are buried under layers of superimposed relevance systems, in relation to which they function just as specific means to bring specific ends of a higher order. Thus these elements of knowledge in hand are characterised by the fact that their proper system of topical, interpretational, and motivational relevances has been truncated. <u>Routine Knowledge</u> which term may be used for this subdivision of knowledge in hand, to differentiate it from the subdivision of <u>existential knowledge</u> - is knowledge for the sake of other knowledge, the relevance system of higher order pertaining to the latter supplying the lost, truncated relevance systems properly belonging to the former. Thus the elements of routine knowledge are no longer experienced as topics in themselves; they seem to be objects pertaining to the lifeworld as such, within which they have well defined place and function.

As an example, any quantity surveying undergraduate can determine the moment when the approach to measurement ceases to be a habitual possession at hand and can be freely mastered as tool. This is the stage when the step by step approach turns into free flowing action; the construction details are then not merely recognised and classified when encountered but are perceived as part of a whole measurement exercise, the approach to measurement has become a utensil in hand. Existential and routine knowledge are elements of the stock of knowledge at hand which cannot be explained in terms of mere familiarity.

The term 'familiarity' covers many heterogeneous situations and James' (1983) distinction between "knowledge of" and "knowledge about" seems to aim at the separation of at least two of them.

Every estimator knows that it is more expensive to build in Central London than it is in Newcastle upon Tyne, yet he may know very little of the complex interaction of supply and demand theory which creates this situation

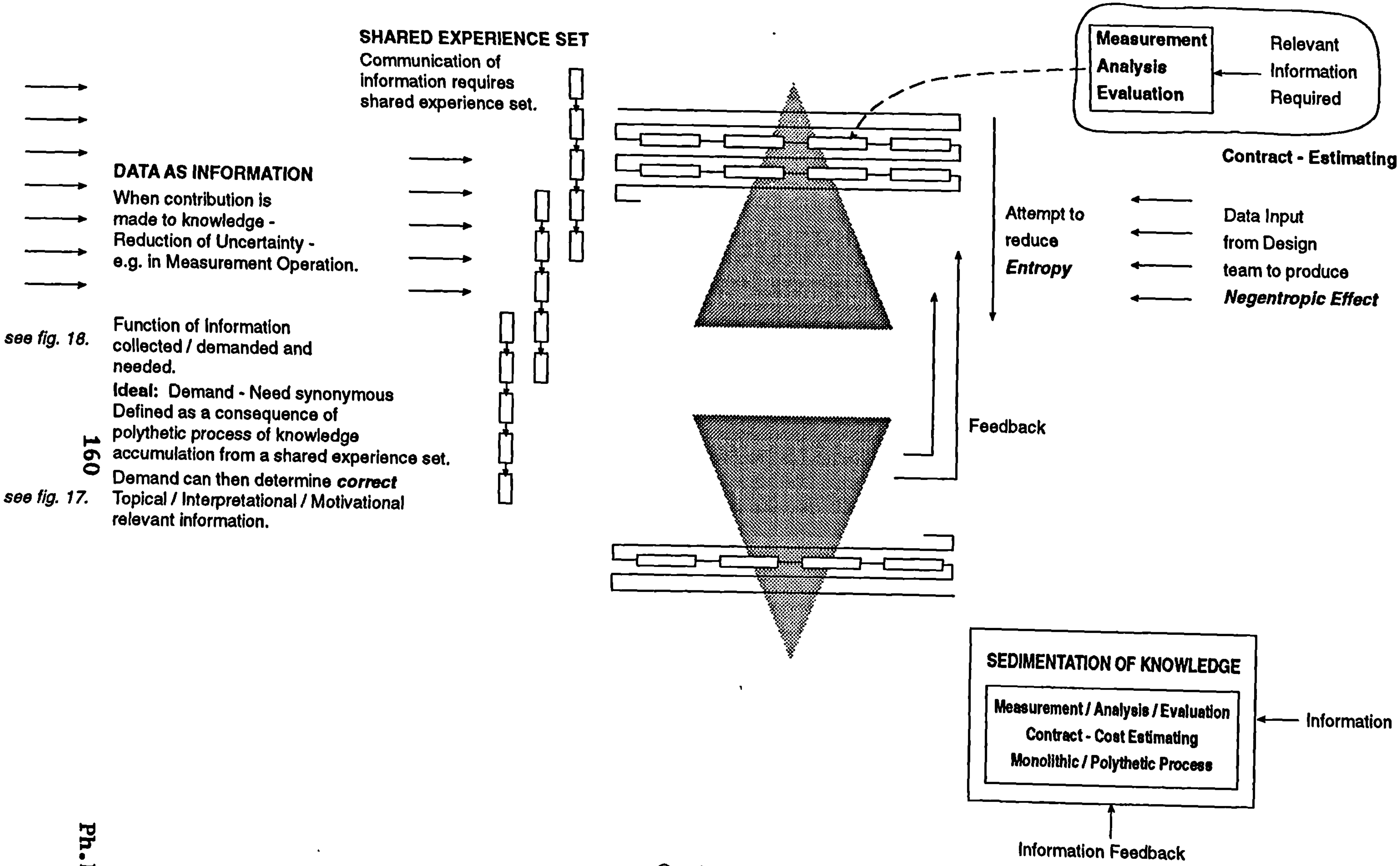
It could be said that the difference between the two levels of knowledge can be explained by its sufficiency for the purpose at hand, which is determined by the systems of motivational relevances prevailing at the time in any particular situation.

The limits of prevailing motivational relevance may be expressed by such words as "we are not interested in" the details of the mechanism. By this very lack of interest these details can never become topically relevant and therefore cannot originate a system of interpretational relevances set in motion to solve the problem involved in the topic. In the present case it may be assumed that the knowledge of the details involved would be as a matter of principle attainable, if it was thought worthwhile to bother with the procurement of the necessary information. But, in this case there is no inducement to do so. For the present purpose at hand such information is not required; it is sufficient for the estimator to know that it is more expensive to build in Central London and to be aware of the value of the difference. It may be suggested that estimating activity is conditioned by previous sedimentation of knowledge to a level of motivational relevance sufficient for the purpose at hand. This is why there is no perceived need to change (Hardcastle 1978). Further, this will impact upon his information demands and his perception of his information wants. Thus the acceptance of this 'routine knowledge', no matter how obtained has a significant impact on the approach to definition of the system. Indeed, as Siegler (1975) has noted "learning is determined by the interaction of knowledge and experience, and experience that contradicts existing rules promotes the most learning".

Schutz (1970) considers the unquestioned but questionable regions of the lifeworld as in principle knowable but not worth knowing - at least "for the time being", "in the present context", "from our point of view". As long as this region does not interfere with the matters I am topically concerned with now, I simply take it for granted as a matter of indifference. Actual knowledge refers to potential knowledge, as such one may speak of the unquestioned world as the realm of attainable knowledge, i.e.the "unknown".

Two cases have to be distinguished within this particular category of the unknown - that which was formerly known and knowledge of which can be restored:
The formerly actual knowledge has been lost and has to be reconstructed. This loss may either refer to some elements of a unified meaning-context which has been preserved as actual knowledge; or the meaning-context itself may be lost, whereas some of the elements which constituted it may be preserved. The first case may occur if knowledge acquired polythetically is actually accessible in a monothetic glance, whereas the polythetic steps leading to this sedimentation are forgotten .

The second case may occur if one of the unifying factors from which the meaning-context originates disappears. This would be the case, for instance, if for pathological reasons the functional unity of our organism breaks asunder; or if the apparent coherence of an object of the outer world proves to be inconsistent; or if the fringes of a symbolic system lose their connective power and so on.




**Quatenary Model**

**Figure 16.**

This is of crucial importance for as Faibisoff and Ely (1976) note, "There are individuals who can articulate demands and there are those who have a desire for information but are not able to specify what it is that they need", and Brittain (1970) states, "A user may know that information relevant to his work is available and makes a demand to an information source. At the other extreme is the individual who makes very few demands but has many needs." Parker and Paisley (1966) conclude "Real needs may go unexpressed if users consider them to be unrealistic (i.e. not capable of being realised by existing systems)".

Ogunlana (1985) argues that the findings of Morrison and Stevens (1980) and Thorpe (1982) demonstrate that there is a causal link between estimators ignorance of the magnitude of error in estimates and their lack of recognition of the need to learn from experience. No research has so far demonstrated this causal link and the foregoing discussion would suggest that this suggestion is limited in its understanding of how knowledge is accumulated. For while noting that Pryzczynski and Greenberg (1981) and Feldman (1986) have "demonstrated that when events that disconfirm expectations are made salient, an active process of searching for information may begin", as noted above there remains the issue of the estimators sedimentation of knowledge which dictates how he will perceive his information needs. Thus while the 'search for information may begin' it will rapidly come to a stop if there is no perception that the information will be available nor of what information would be salient (Ross and Anderson 1982).

An alternative posit is given here. If the polythetic steps are lost, or indeed belong to the pre-history of the estimator who accumulates his knowledge monothetically from his peers then it is unlikely that he will be able to articulate his needs.

As a consequence it may not be possible to correctly identify the relevant information. In turn the question Q in the model,

$$I_1^2 = Q_{TIM}/([(f_1^2\ f_{orm})(1-M)][1-D] + K_1^2 - R \tag{14}$$

is not well defined.

# CHAPTER 6

# INFORMATION RELEVANCE AND ESTIMATING

## 6.1 Relevance

In 1974 the SMM development Unit reported that "The ability to visualise conditions and to gather relevant information are characteristics which the estimator must possess if he is to submit a profitable bid for a project" and in 1989 Ogunlana noted that "If cost relationships are developed at the element level, cost variances should also be determined at that level. This will make learning easier since outcome feedbacks are more relevant to expectations of design estimators". These statements may be true but there remains no unequivocal evidence which at present can be used to identify what is 'relevant' or what is understood by this term. This is particularly important as in a survey carried out by Ogunlana (1989) of 8 design offices the contribution of expertise to cost estimating is in three areas; ability to select relevant cost data better than others, ability to establish cost relationships and design parameters; and intuitive abilities necessary for adjusting rates acquired through familiarity with projects. The first noted being the most important.

In the development of a program to monitor accuracy of estimating Ogunlana (1989) noted the requirement for, "relevant information about the process and data used for estimating including the estimator's opinion about market conditions and other related variables that are likely to affect the accuracy of cost predictions".

Wilson (1973) has stated that "relevance is not a single notion but many. Or rather, relevance is a highly general and vague notion that can be made specific and precise in a large number of ways. Different specific notions of relevance enter into the specification of different imaginable or actual information systems, and different notions of relevance are appropriate to their evaluation".

Definitions of relevance were so numerous that Rees and Schultz (1967) found it almost impossible to identify the sources and authors; instead two lists were constructed that summarised the definitions.

Relevance is;

...Correspondence between a document and a question; a measure of informativeness of a document to a question;

...An indication of how good or satisfactory an answer document is to a question;

...The degree of relationship (relatedness, overlap, fit) existing between a document and a question; the degree of fit between document and prior knowledge of user;

...A property which assigns members of a file to the answer;

...Appropriateness of a document to a question;

...A measure of surprise that something appearing in a document is connected with ones information need or question (i.e. that it is previously unknown information and/or previously unrelated information);

...Relatedness of information to the question even if the information provided is known or outdated;

...A measure of usefulness of an answer;

...An indication of significance to an important purpose;

...A satisfactory answer;

Relevant materials or information are:

...Documents from which answers to questions could be inferred;

...Ideas or facts so closely related to the problem at hand that disregarding them would alter the problem;

...ideas or facts useful in considering the matter at hand;

...answers of use in current work;

...answers required for professional growth;

While the above provides a list of possible definitions of relevance, the approach below shows relevance as an algorithm, showing relationships among parts while permitting manipulation of the parts.

Relevance is the A of a B existing between a C and a D as judged by an E;

where A represents the gauge of measure;

B represents the aspect of relevance;

C represents the object upon which relevance is measured;

D represents the context within which relevance is measured;

E represents the assessor.

Saracevic (1975) sees "relevance as a measure of the effectiveness of a contact between a source and a destination in a communication process". Like so many things in life relevance is a relative concept. Some things are more relevant than others, some things are not relevant anymore, and some have a chance of becoming relevant. Relevance depends a great deal on what is already known for information is not necessarily relevant as a response to a question.

A criticism of the above is that they do not first establish primitive terms and then proceed to more complex definitions, using proofs or evidence where necessary; but simply substitute terms that are as undefined as the term which they tried to define was at the outset. The advantage of paraphrasing definitions is that such definitions provide a preliminary context.

When in communication with no particular outcome in mind relevance plays little or no role. However, if and when any productive contact is desired the intuitive notion of relevance is used, (Saracevic 1975), where relevance is defined as a measure of information conveyed by a document relative to a query, (Gourmand 1964). "In the most fundamental sense, relevance has to do with effectiveness of communication", (Saracevic 1975) and "Information has many associated properties, and relevance is one of the most important ones", (Saracevic 1970/72). As noted earlier information is sought in response to a query (question) with a view to reducing uncertainty. As such one might expect relevant information to make a contribution to this.

The better one understands the meaning of relevance from different points of view, the better one understand "systems of relevance" (Schutz 1970), the better information systems can be built. "The better we understand relevance, the better chance we have of avoiding failures and of restricting the variety of aberrations committed in the name of effective communication", (Saracevic 1975).

Wilson (1973) makes a basic distinction between psychological and logical relevance. The latter deals with actual uses and actual effects of information. The former is a double concept "of a relation between an item of information and a particular individual's personal view of the world and his situation in it; and it is a concept in which relevance depends on logical bearing on some matter on which he has preferences".

It can be stated that information communicated that is not relevant is not information, but such an approach is limited and deficient, since it does not take into account a number of possible viewpoints on relevance of information in a communication process. For instance relevance may be considered from the points of view of the source or a variety of sources of information, and from the points of view of the destination or a variety of destinations to which information is transmitted; in addition a variety of representations of information as well as transmitting or processing aspects may have to be taken into account.

The notion of relevance is directly connected to the concept of communication as a process. A communication process is viewed here as a sequence of events where information is transmitted from one object (source) to another (destination), and often in a series of iterative sequences (see Figure 16). The objects, sources and destinations may be people, organisms, records, machines, or systems in general (Shannon and Weaver 1949). This view of communication implies that both the source and the destination contain, among other factors, a store, file or memory of knowledge and/or knowledge based constructs (Kemp 1974).

It is suggested therefore that relevance may be understood to be a fundamental aspect of human communication, the effectiveness, of which depends on a great many factors which could involve different criteria. It is also relative. Some things are more relevant than others, some things are not relevant any more, and some have a chance of becoming relevant. Relevance depends a great deal on what we already know and on what is generally known. It is therefore a function of the sedimentation of knowledge, (Schutz 1970), of the estimator/quantity surveyor (expertise, Skitmore 1985), which in turn is determined by how this knowledge was accumulated, i.e. polythetically or monothetically, (Schutz 1970). "Any measure of information must depend on what is already known: a fact which must be recognised in any assessment of a document with respect to a query", (Goffman 1964). Thus an expert estimator is someone who can sort through information and decide what is relevant to the prediction process for he is a person with a high level of knowledge of the factors which impact upon estimating accuracy (Feldman 1986).

Psychological tests have shown how people differ in their perceptions of relevance, (Cuadra and Katter 1967); but psychological tests do not settle questions about whether perceptions are correct or not. This is of particular concern to the analysis of the efficacy of any information system as it highlights once again the difficulty of differentiation of information needs and wants (see earlier), and the consistency of view between the information provider (Quantity Surveyor/Estimator) and the information receiver (Estimator/Quantity Surveyor). "The sort of criticism we are all ready to engage in rests on assumed standards whose analysis and elaboration is a task for logic, not for psychology" Wilson (1973).

Factors that predominate in determining relevance, include, "what we think we want and how we ask for it; how we understand what is asked and what we think is really asked; what is wanted in contrast to what is really needed; who is asked, who is asking; what the situation is; what will be done with what is provided; and so on", Saracevic (1975), also (Faibisoff and Ely 1976).

Hence relevance and relevant information which reduces uncertainty, is a function of the query (question asked).

(14) $$I_1^2 = Q/([(f_1^2\ \text{form})(1-M)][1-D] + K_1^2) - R$$

Where;

(15) $$I_2 - I_1 = I_{Rel}$$

and

(16) $$I_{Rel} = fQ$$

As relevance can be looked at from different points of view, there results a particular problem in regard to any attempt to investigate the role of information within a communication process which has not previously been defined within the context of a suitable model. This is the case in regard to that cyclical and iterative process within which the activity of cost estimating takes place. The role of information has been documented in earlier chapters of this work, but, the logic, and psychological views of relevant information have not been considered.

The different views of relevance have emerged because in the communication of knowledge there are a number of dynamically interacting systems of relevances organised in some stratified or perhaps hierarchical fashion of complex systems (Saracevic 1970/2). It may be postulated that there should be some fundamental properties that are universal - common to all views or systems of relevance - and some unique properties that are specific to each system. Saracevic (1970/2) has speculated that among the universal properties are:

> Knowledge, knower: all views assume a prior existence of a body of knowledge, or ideas or facts or their representations; or of a knower.
> Selection: implied by all views is a process of selection concentrating on elements or structure of above knowledge.
> Inference: selectivity is based on some form of inference.
> Mapping: the aim is some form of mapping of selected elements or structure of knowledge onto something - at a minimum onto some other elements or structure of knowledge.
> Dynamics: the dynamic interactions among properties are involved; changes in any property over time is possible.
> Association: the internal structure of elements of knowledge and other properties affects the dynamics and vice versa.
> Redundancy: more than one set of elements of knowledge, pattern of association or structure, form of inference, dynamics or mapping may satisfy the criteria of any and/or all properties.

If the properties suggested by Saracevic (1970/2), or similar properties are indeed found to be universal to all views or systems of relevances, then an explication of each view will be incomplete if it does not in some way incorporate an explication of every one of the universal properties. Thinking on relevance can therefore proceed in various directions, such as:

Taking a given view or system of relevance and proceeding to fully define all properties. Taking a given property in one or a number of systems and defining and contrasting the nature of the property; for instance, deductive, inductive, probabilistic, preferential etc. Taking a number of properties and explicating the interplay. Taking a number of explicated systems of relevance and explicating the interplay between them. The ultimate thinking on relevance will be the one that explicates the interplay among all explicated systems of relevances.

Within the context of the development of a paradigm of communication in construction which would ultimately lead to the explication of the interplay among all explicated systems of relevances, what is required at this stage is the creation of a well founded model of the process and the identification of the systems and their relationships.

Much work has already been done in earlier chapters in developing this model which results in the need to focus on the relevance systems.

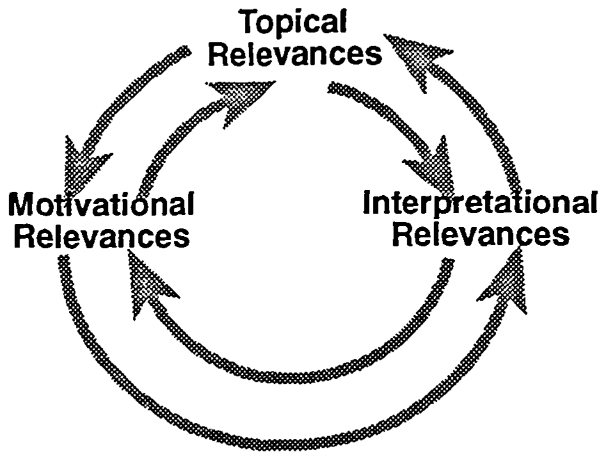
As noted earlier, communication of knowledge is effective when and if information that is transmitted from one file results in changes in another. In the context of decision making this would be an increase in the grade of organisation. Relevance is a measure of these changes.

Changes consist of additions to, deletions from, or reorganisation of the files of knowledge and/or the files of representations. One can take a much broader view and argue that communication of knowledge is effective when and if it has directly observable results such as changes in action or behaviour. The argument is deficient in that such results are effected by a great many other factors, in addition to, and unrelated to, the communication of knowledge.

## 6.2 Psychology, Logic and Relevance

The most powerful psychological discussion of relevance has been provided by Schutz (1970), who contended that the social world ("lifeworld") is not simply one homogeneous affair, rather it is articulated or stratified into different realities, with relevance being the principle at the root of the stratification of the "lifeworld". Schutz elucidated three interdependent systems of relevances: topical relevances, motivational relevances and interpretational relevances. The circular interrelationship is shown below, Figure 17.

What Schutz (1970) calls "the world of working", is one's "paramount reality". It is the world of physical things, it is the realm of locomotion and bodily operations, which may offer resistance which requires effort to overcome it; it places tasks before a person and is the setting in which plans and tasks are carried out, and in which one fails or succeeds (e.g.




Relevance Model
Figure 17.

estimating). "Working" means "gearing" into the outer world, which indicates action on the social scene which may then change it, modify the objects in it and their various relations. Gearing into the world of working also includes communication, hence it is the world in which language has its primary locus and origins. This is supported by Cooper's (1971) aim which is "to define relevance as a relationship holding between pieces of stored information on the one hand and user's information needs formulated as information need representations on the other hand"; the possible answers that replace questions are construed as being "linguistic representations of psychological states of need for information".

Insofar as it refers to the world handed down to a person (by his/her "tradition"), this assumption combines with the knowledge derived from previous experience to form what Schutz (1970) calls "stock of knowledge at hand." By means of this progressively sedimented stock of experiences, the objects, events, and people encountered in the course of life are experienced as "things of such and such a kind," (Schutz 1970). Inevitably, this suggests that this classification is an essential part of any interpretive mechanism. Within the predictive sphere of estimating it may therefore be hypothesised that the approach to estimating is conditioned by the sedimented stock of experiences which in turn dictates what may be construed as topically relevant for a particular "gearing" into the outer world, (e.g. estimating) and that experts are those with the most comprehensive stock of knowledge. As Ashley (1988) has noted in regard to conceptual estimating in a survey of 29 companies the most important issue is estimator experience and expertise (59% of companies) followed by availability of a complete scope definition (52%).

A cyclical process is set up which compounds and confirms the approach to gearing. Whether the approach to gearing and therefore estimating and the choice of relevant information is correct, has not yet been proven by researchers nor has the consistency of "lifeworld" (Schutz 1970) between the two major senders and receivers of cost information (i.e. the quantity surveyor and the estimator) been determined. Indeed it could be argued that the work of Skitmore (1985) and Ogunlana (1989) suggests that the 'choice of relevant information' is in error for as more data is provided little improvement in estimating accuracy ensues. This conclusion would appear to be supported by other researchers, the work of which is reported in Chapter 1. Yet, Ogunlana (1989) has noted that in an opinion survey of factors affecting estimating accuracy (8 offices) historical cost data and estimating expertise were rated equally highly while in a strength of feelings rating historical cost data is most highly rated.

In an investigation into the choice of historical project information for use in estimating Ogunlana (1990) has noted that source credibility plays a vital role in an estimator's choice of information. There is also a demonstrated desire to make the features of the historical project as similar as possible to the proposed project and average estimators tend to be unwilling to change the criteria for choice of projects while novices tend to be more analytical. There thus appears to be an attempt to achieve consistent 'gearing' which is based upon previous 'sedimented stock of knowledge'.

The world is the framework and the object of an actors actions. To carry out plans and projects, (e.g. estimating), one must act on it, change it, and experience its resistance to effort; thus, in the paramount reality the interest is pre-eminently pragmatic (Schutz 1970). This is consistent with the notion of a logical view of relevance which is based on the concept of a relation between an item of information and a particular individual's personal view of the world and his situation in it and it is a concept in which relevance depends on logical bearing on some matter on which he has preferences.

Cooper's (1971) definition of logical relevance is that "a statement is relevant to a question if it belongs to a set of statements, a non-redundant or minimal premiss set of statements, from which an answer to that question follows logically". The definition of logical relevance thus depends on the concept of logical consequence. Thus an item of information would be logically relevant to the activity of estimating if it contributed to a more accurate assessment of cost, (indeed, if it lowered the entropy of the system from the decision maker).

Schutz (1970) argues that the world is organised into a hierarchy of "zones" within actual, potential, and restorable "reach", at the locus of which is the actors immediately available "manipulatory sphere".

This professionally and biographically determined situation must be defined and come to terms with in order to make a decision. This essentially historical situation is the sedimentation of all previous experiences, and this "stock of knowledge at hand" is that in terms of which one may act at any moment, that through which one can interpret and experience the lifeworld.

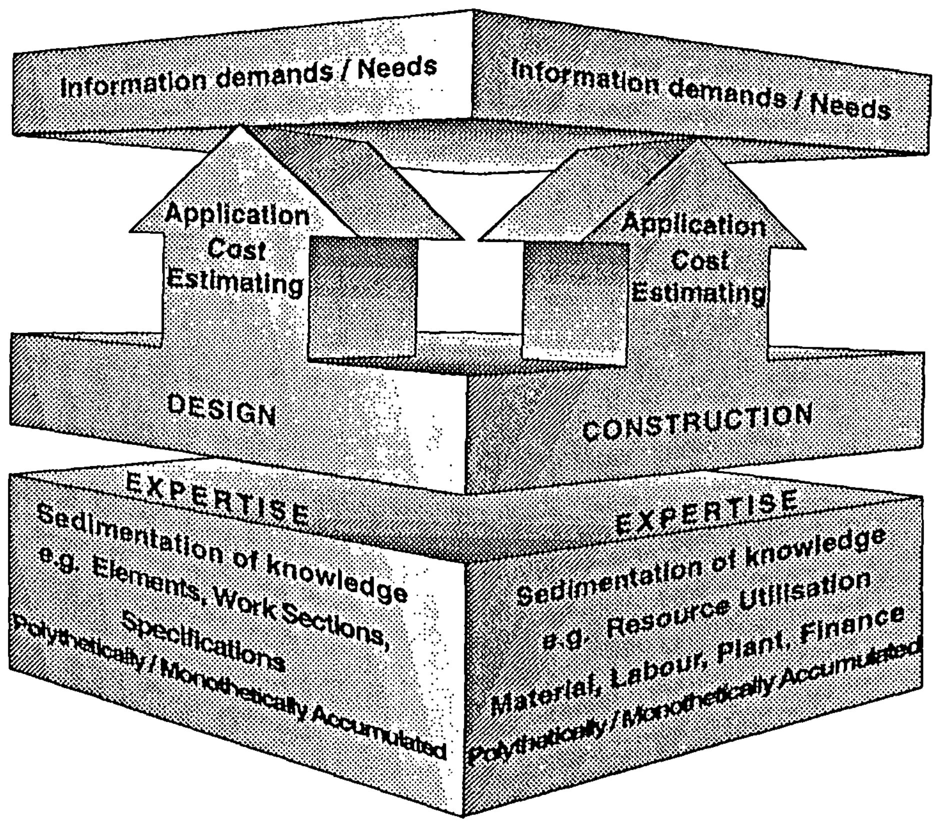
Thus the question Q which seeks perceived relevant information is a function of the sedimentation of experiences.

$$Q = fE_{Sed} \tag{17}$$

All anticipations and plans refer to previous experiences now at hand, which enable one to weigh chances. But Schutz (1970) states that this is only half the story. What I am anticipating is one thing, the other , why I anticipate certain occurrences at all. "What may happen under certain circumstances is one thing, why I am interested in these happenings and why I should passionately await the outcome of my prophecies" (Schutz 1970). It is only the first part of these dichotomies which is answered by reference to the stock of experiences at hand as the sediment of previous experiences. It is the second part of these dichotomies which refers to the systems of relevances by which man within his natural attitude in daily life is guided (Schutz 1970).

"In the horizon of the thematic field, I find not only the perceptual experiences originating in my present spatial position. There is as well my auto-biographical situation at the present moment, which is itself but the sedimentation or outcome of my personal history, of all the experiences I have had and which are preserved in my memory or are available within my present stock of knowledge at hand" (Schutz 1970). Included in the latter are not only what has been experienced at first hand, but also socially derived knowledge, which points to the experience of others (both contemporaries and predecessors). The balance and impact of experienced at first hand and socially derived knowledge is as yet unclear in many processes and certainly so in cost estimating. What would seem to be clear is the distinction between the quantity surveyors experienced knowledge, that of the contractors estimator and that of the contract production team (see Figure 18). Nevertheless, it is the investigation of the problem at hand which is now thematic, and the field of perceptions, of autobiographical recollections, of social relationships, of socio-economic determination and so on, forms merely the horizon of this focused activity.

The first object of analysis is the field of consciousness, in so far as it is structured into a "thematic kernel" (Schutz 1970) which stands out over against a surrounding horizon and is given at any "now" of inner duration. Husserl (1983) has investigated the functions of the "attentional ray" for the constitution of the thematic kernel and therewith for the structurisation of the whole field. What constitutes one (one strain) of these temporarily ongoing and simultaneous




Expertise Model
Figure 18.

experiences as the thematic one is the fact that it has been voluntarily turned to.

The activities of consciousness, the "turning to" and "turning away from" certain experiences which makes them thematic or non-thematic, i.e. horizontal - takes place within a very restricted scope of discretion, (consider Shackle 1955).

These activities themselves have their history: they are the sedimentation of previously experienced events and are thus themselves constituted and interconnected in an experiential framework or context. It can be seen that there are two different problems here:

1. the question of the relationship between theme and horizon within the field of consciousness at any given moment of inner time; and
2. the motives by means of which this structurisation has been initiated.

Bergson (1910) has suggested that it is practical interest determining our action in the outer world which circumscribes the elements of the field of consciousness which can be grasped by the intellect. By delimiting and determining the segment of our experiences of the world which, in our language becomes thematic, the intellect pre-delineates the lines to be followed by action. While Koch and Deighton (1989) note that individuals give special status to knowledge obtained form experience. It is clear that the practical interest which is common to both estimators and quantity surveyors within the context of this work is cost estimating as a predictive activity.

Within the context of cost estimating at the design stage Skitmore (1985) and Morrison and Stevens (1981) have identified aspects of information which have been considered to be thematic, however within these experiments the participants have not had a free choice but have been directed toward a limited set of criteria.

It has been argued that what is within the field can be virtually apperceived. Anything within the horizon moreover, can be made a theme of thought. But, Leibniz' "small perceptions" (Schutz 1970) cannot be made a theme because according to him they can be apperceived merely "en masse"; but any single small perception is by definition, indiscernible from any other. Applying this concept to estimating would seem to offer some support to the views expressed by Fine (1968) Moyles (1973), Horner et al (1986) amongst others who have identified the difficulties of obtaining consistent and determinable values for minor items in the bill of quantities in comparison to the relative consistency of values which may be found for elements of whole buildings. While the work of Hardcastle et al (1988) has identified the insignificance in cost terms of 95% of the items in a bill of quantities of certain types of work.

It is a precondition of any thematisation that the experience constituting this theme has its own history of which it is the sedimentation. Thus one may be at any time in a position to question this as to its genesis or historical origin. In other words, each theme refers to elements which formerly have been within the field of consciousness, either as a former theme or at least as horizontal and thus virtually thematisable. Neither is the case with small perceptions. Inevitably, in estimating a situation is created in which the estimating activity is consistent with previous experience and as a consequence there is consistent 'thematisation' with subsequent impact upon information needs.

In studying the problem of relevance in the sphere of perception, Jankelevitch (1938) has pointed out that any perception itself involves the problem of choice. One has to choose within the perceptual field those elements which may become in Husserl's terminology thematic and subject to interpretations. Such interpretations do not necessarily have the form of predicative judgements. The passive synthesis of recognition, similarity, identity, dissimilarity, likeness, and so on, are interpretative events happening in the pre-predicative sphere. The recognition of an object as the same or as the same but modified, or the recognition of its modification, are the outcome of such pre-predicative synthesis.

Why does a particular attribute appeal to the estimators attention to such an extent that he makes it the theme of his interpreting activity? What makes the interpretation of this attribute at all a problem to him? There may be many attributes to which he be indifferent, yet they remain in the horizon. It stands out over against them, it is from the outset 'relevant' to him. This may be for many different reasons, and in order to specify these one would need to have full knowledge not only of the situational elements in the present autobiographical moment of the estimator, but all of the history, the antecedent genesis which leads to this actual situation (in other words, of all the sedimentations of which the actual situation is the outcome).

The attribute has been identified as problematic. It became problematic and thus has to be made into a theme and not left in the indifference of the concomitant horizontal background. It becomes problematic to him and therefore thematic.

It has been suggested by Ogunlana (1989) that average estimators operate on a limited number of attributes while novices tend to be more analytical.

In quoting from the work of Kahnerman and Tversky (1973), Ogunlana (1989) notes the impact of the 'base rate fallacy' in the estimators approach to choice of information. Using Hinsz et al (1988) as a source the phenomenon is explained as follows

"Representative Heuristics (Kahnerman and Tversky 1973) - The prediction of outcome is estimated based on the degree that the individuating information is similar to the salient features of the outcome being predicted. If this explanation were accepted, estimators should use data from a past project which has most of the features of the new project.

Causality Principles (Ajzen 1977) - Choosing information to the degree it fits one's intuitive notions about the causes of the events in question.

Vividness (Nisbett et al 1976) - The vividness of individuating information relative to the typically abstract base rate information accounts for its greater influence on judgement. Information that easily catches the attention of estimators is more likely to be used for estimating.

Relative Relevance (Bar Hillel 1980) - Available information is ordered according to its relative relevance to judgement being made. More relevant information is preferred to less relevant information. Bar Hillel further argues that information judged to be more specific to the event in question will tend to be perceived as being more relevant.

Source Credibility (Howland et al 1953, Birnbaum and Steger 1979) - Sources perceived to be inaccurate are often ignored.

The consistency between the evidence the source provides and the accuracy of the source determines its use.

Diagnosticity (Ginoisar and Trope 1980) - The extent to which the information can be perceived as useful for making predictions determines its use. As individual information becomes less consistent, it becomes less diagnostic for making judgement and will be discarded.

Availability (Bar Hillel 1980) - Information that is more readily available will be used. Vividness of information may also aid its availability to potential users. Media advertisements tend to work on this principle.

Completeness (Bar Hillel 1980) - Information that seems more complete will be seen as having better predictive ability than less complete information.

## 6.3 Topical Relevance

This is the first form of relevance: namely, that by virtue of which something is constituted as problematic in the midst of the unstructuralised field of unproblematic familiarity - and therewith the field into theme and horizon. "To make an object a problem, to make it the theme or topic of our thought, means nothing else than to conceive it as a dubious and questionable one, to segregate it from the background of unquestionable and unquestioned familiarity which is simply taken for granted", (Schutz 1970). Within the context of estimating the term 'dubious' refers to the doubtfulness of the impact of that attribute upon the value of the item (or the project). This experience does not become thematical by a volitive act and that is why this kind of relevance is termed imposed relevance.

The following comments concerning the nonimposed topical relevances may be restricted to the voluntary superimposition of one theme by another while retaining the first in ones grip. Through such superimposition, new topical relevances come into play. New data hitherto within the horizontal field of the first theme, become drawn into the thematic kernel. Husserl (1983) has pointed out that horizon has a two fold meaning: outer and inner horizon. The outer horizon is used to designate everything which occurs simultaneously with the theme in the actual field of consciousness. But as well it is used to designate everything that refers by means of retentions and recollections to the genesis of the theme in the past, and by means of protentions and anticipations to its future potentialities. Beyond this the outer horizon refers to everything connected with this actual field as the outcome of passive syntheses such as similarity, likeness and dissimilarity.

There is also the inner horizon. Once the theme has been constituted, it becomes possible to enter more and more deeply into its structure: first through describing as completely as possible its features and their uniqueness, and then by analysing its elements and their interrelationships and functional structures determining the process of 'sedimentation', of which it is the outcome, and eventually by re-establishing and re-performing the polythetic steps by which its meaning, grasped now in single monothetic glance has been constituted (Husserl 1983). Problems occur however in situations in which the sedimentation of knowledge did not take place by means of polythetic steps but rather as a monothetic process picked up from ones peers or dictated by ones auto-biographical situation. Again reviewing the estimating process, the ability of an estimator to re-create the polythetic steps by which knowledge of values may or may not have been accumulated remains questionable.

Theme and intrinsic topical relevances are two names for the same configuration. By entering into and explicating the inner horizons, by putting into play these hidden potential topical relevances the theme remains constant as the determining factor of all such sub-thematization.

This system is one of intrinsic topic relevances, as opposed to the imposed topical relevances already discussed. Whereas in the latter system the articulation of the field into theme and horizon is imposed by the identification of some doubtful attribute,it is characteristic of the system of intrinsic topical relevances that one may or may not direct attention to the indications implicit in the paramount theme.

The above parallels the definition by Wilson of situational relevance. Situational relevance is relevance to a particular individuals situation - but to the situation as he sees it, not as others see it or as it "really" is (Wilson 1973). This is relevance which is defined by the concern of the information user and not just his interest.

Situation relevance is also relevance in relation to an individual's stock of information and changes as that stock changes. For a potentially relevant item to become actually relevant, an information user must learn of it and accept it at least tentatively. Further, if given information by others who believe it to be relevant it may not be believed, what is potentially relevant becomes actually relevant only by being accepted. As Wilson (1973) notes "for an item to be situationally relevant it must be one of my stock of beliefs, it is not necessary, for an item to be situationally relevant, that I think it relevant".

While situation descriptions include only statements that are members of concern: the notion of situational relevance requires that we consider not only what a man knows about the world that falls within the sphere of his concerns, but further knowledge in which his preferences may not enter at all, (Schutz 1970). "The whole stock of his knowledge, his entire image of the world, stands in potential relation to the situational knowledge that represents the subpart of concern to him", (Wilson 1973).

It must also be noted that by the establishment of the paramount theme as home base both the direction of the intrinsic relevances leading into the horizon and the limit up to which they must be followed are to a certain extent already constituted.

It is the set of "actual interests" which itself depends on the autobiographical and situational circumstances of the individual that limit what is commonly called the level of investigation. Thus the autobiographical and situational circumstances of the estimators, whether they be quantity surveyors or contractors estimators is of particular interest here as it determines that which is thematic or topically relevant.

Then;

$$Q_T = fE_{Sed} \tag{18}$$

Where $Q_T$ is the well defined question as determined by the imposed topical relevance.

## 6.4 Interpretative Relevance

If one may assume that the doubtful attribute is now thematically given to the estimator for interpretation. Then it follows that in resolving this doubt he must now seek to grasp the meaning of what is now within the thematic kernel of his conceptual field. He must interpret it, and that means that he has to subsume it, as to its typicality, under the various typical prior experiences which constitute his actual stock of knowledge at hand. The difficulty which new forms of communication media experience in being accepted is one which is reflective of the desire for users of the communication document to be able to relate the areas of doubt with previous experience and the problem of doing so when there is no direct similarity of reference. At this point one should consider the the work of Hardcastle (1978) and Ogunlana (1989).

This type of relevance based upon prior experience is different to that identified so far and may be termed interpretative relevance (Schutz 1970).

It is suggested that this relevance has a double function. It is interpretatively relevant if that part of the stock of knowledge at hand has "something to do" with the thematic object now given to interpretation, further, certain particular moments of the object perceived obtain the character of major or minor interpretative relevance for the task of recognising and interpreting the actual experienced segment of the world.

The familiarity of this expectation may reach such a high degree that no thematic relevance will be imposed upon an observer of such an object.

Wilson (1973), interpreting this as evidential relevance states that it occurs if, an item of information Ij is relevant to a conclusion 'h' in relation to premise 'e' if the degree of confirmation, or probability, of 'h' on evidence 'e' and Ij is greater or less than the degree of confirmation, or probability, on 'e' alone. "Relevant information is that which strengthens or weakens a case; irrelevant information is that which does neither" (Wilson 1973).

It may be argued that it is impossible to identify these 'preferences' as preferences are not independent of each other. As von Wright (1963) has stated preferences have a "holistic character, to which the "atomistic" assumption that one could state preferences to different answers to questions taken one at a time is completely inadequate. This impacts on any proposed methodology for investigation of relevance. However Wilson (1973) states that "we must (also) suppose it possible to elicit his preferences 'as things now stand', i.e. whatever his current views about the situation and his preferences in other sorts of cases may be. We may, I think, admit that preferences in a single case would not be what they are if the whole context of views and preferences were different, but still suppose that we can elicit those current preferences one set at a time, and without in each case making explicit the implicit dependencies of preferences on each other and on factual information".

However, where one is heading and where one has been are parts of one's current view of where one is, i.e. the experiential base developed from the sedimentation of knowledge and the context in which the information is to be used. It must be recalled that a situation description contains only concern set members; so that the situation description that contains statements about past and future extends only so far as past and future are of concern. One should note here that if historical information is not available to estimators in the correct form then it would not be recognised as being of concern and would not therefore fit into his set of preferences. Thus indicating a breakdown in the information system. Further as noted above, while there are preference orders on sets in respect to future and past, it is not necessarily so that the preference order for possible states of affairs now is the same as the preference order for some analogous states at some future time.

"The basic notion of situational relevance is the same: an item of information is situationally relevant, whether the situation be past, present or future, if it, on a given stock of information implies or is evidence for or against one or another of a concern set, where the concern set is "dated", that is, is indexed temporally as is the situation description, (Wilson 1973).

It may be that an item of information was highly relevant to a question of small concern, or slightly relevant to a question of large concern. (the product of degree of relevance and degree of concern could measure the importance of the item.)

However, it should be noted that as with topical relevances there are no such things as isolated relevances. They are always interconnected and grouped together in systems. This has been termed the principle of compossibility (Leibniz 1973) of all its coexistent moments.

Then;

$$(19) \qquad Q_{TI} = fE_{Sed}$$

Where $Q_{TI}$ is the well defined question as determined by the imposed topical relevance and interpretive relevance.

## 6.5 Motivational Relevance

The importance of interpreting correctly, to a satisfactorily plausible degree, (Schutz 1970) consists in the fact that not only the means to be chosen but even the ends to be attained will depend upon such a diagnosis. The satisfactorily plausible degree of interpretation opens a relatively high subjective chance of meeting the situation efficiently by appropriate measures. This type of relevance has been termed motivational relevance by Schutz (1970). With respect to human action therefore, any statement of causal relevancy can be easily translated into terms of motivational relevance and the adherent systems of interpretational relevance.

In more general terms, motivational relevances are sedimentations of previous experiences, once topically or interpretationally relevant, which led to a permanent habitual possession of knowledge, remaining dormant as long as the former topical relevances do not recur, but which become actualised if the "same" situation or a typically similar one recurs. This is an extremely important aspect of the process of estimating, for if as posited by Ogunlana (1989), "design cost estimators are not learning adequately from their previous performances in estimating, then difficulties arise in identifying 'same situations'.

Then;

$$Q_{TIM} = fE_{Sed} \qquad (20)$$

Where $Q_{TIM}$ is the well defined question as determined by the imposed topical relevance, interpretive relevance and motivational relevance.

This typicality not only refers to already acquired knowledge but at the same time to a set of expectations adhering to such knowledge, namely, typicality refers to the set of expectations that future experiences will reveal those typical traits to the same degree of anonymity and concreteness (Schutz 1970).

Thus, suppose that an estimator has accumulated sufficient "knowledge of acquaintance" (Schutz 1970) with a particular unique costing problem to have permitted him to cost it and then leave it. To what extent could it be said that he had familiarised himself with it sufficiently for him to come to terms with it? Schutz (1970) would argue that as long as he had not yet grasped the typicality behind the atypical unique configuration with which he had to come to terms, he cannot store away the acquired familiar knowledge in neutralised form for later use as a habitual possession. At least, the expectation of recurrent typical experiences is required for the full meaning of the familiarity of knowledge. Thus, familiarity itself, and even knowledge in general (considered as one's habitual and dormant possession of previous experiences), presupposes the idealisations of "I can do it again".

On the other hand any experience which has become part of ones habitual possession (and therefore familiar) carries along with it its anticipations that, as a matter of principle, certain future experiences will be recognised as refering to the same previously experienced objects, or at least to objects which are the same or typically similar to it.

From this point of view, familiarity has a particular subjective meaning, namely that of being sufficiently conversant with an object of one's experience for the actual purpose at hand. So formulated the concept of familiarity demarcates, for the particular subject in his concretely particular life-situation, that sector of the world which does not need further investigation. Whether or not this aspect which does not need further investigation is consistent for a particular profession or persons involved in an identical activity is unknown but would seem unlikely.

## 6.6 Signification and Pertinence

Accepting the above and the aspects of, topical, motivational and interpretational relevance it is clear that it is not possible to request a complete situation description, for there is no definite, complete description to give. Further, one would not want necessarily the completest possible situation description. For the individual estimator will know more about his own situation than anyone else, and what he already knows, he does not need to be told. What is wanted is new information, information not already incorporated in his view of the situation. Wilson (1973) calls this significant information if it is directly relevant situationally, and if it is new information to the recipient at the time of its receipt, and reports a condition that is either higher or lower in preference than the condition previously thought to exist (i.e. a change for the better or the worse), or if the same in preference, is correlated with an expectation of change for better or worse on the part of the recipient. Significant information is then information reporting significant changes in a situation, or reporting no change when a change for better or worse had been expected.

One may also want to be supplied with other sorts of information, to extend the notion of significance to information that is indirectly relevant situationally, but which provides inductive evidence for one or another member of a concern set (motivational/interpretive relevance). Though they do not change the view of the situation, they may significantly change the confidence or probability assigned to a component of a situation description. But where such accretions of evidence do not significantly change the confidence assigned to a component of a situation description then they could be understood to be at least redundant and at most noise. In consideration of the above Wilson (1973) postulates that "the only route for exclusion of indirectly relevant information as insignificant seems to be this: if on our evidence it is certain that the world is in one of a certain range of states, among which we are indifferent, then, evidence to the effect that the world is in any one of those particular states is insignificant". This statement should be considered in the context of the assumed Pareto distribution to be found in the bill of quantities, (Moyles 1973, Hardcastle et al 1988), i.e. to what extent are the minor value items situationally relevant? They are certainly not significant in value but may well provide interpretational (indirect) relevance. Significance in the case of indirect relevance thus depends on confidence as well as on preferences and on novelty of information. "As the significant directly relevant information informs of a change from one state to a better or worse one, so the significant indirectly relevant information informs of a change of likelihood as between a better and a worse state" (Wilson 1973).

Signification, can be therefore defined as the significance of the information to the system processing it. The more any given repertoire is analysed atomistically and non-contextually, the more data, and the less signification, the repertoire has. Here, once again one might quote the work of Fine (1968), McCaffer (1976), Moyles (1973). each of whom has identified the comparative variation in item rates relative to tender prices.

Individual letters in linguistic messages carry high information content, for instance, but practically no signification, for signification, like meaning, depends upon context, and the more context there is, the more there is redundancy (low information content) in the use of the repertoire.

As McKay (1969) explains, any system emitting, receiving or processing information uses the information to organise and direct the energy necessary for 'work' to be done, by, within, or outside the system. Thus, whereas information is a necessary condition for signification, it is not a sufficient one. The important similarities between information and signification lie in the processes involved: both depend on coding and decoding, and both depend upon the selection of sequences out of a field of possible sequences.

Clearly, internal aspects of any system affects its performance. How a source manipulates information certainly influences the effectiveness of the contact with the destination, but it is not the exclusive aspect that enters into considerations of significance for a major aspect of significance is that which is related to the selection of information into the system. An aspect which is clearly distinct from the process of selecting information from a system, a process influenced by such concepts as the base rate fallacy and relevance.

This is a crucial factor, for the bill of quantities which evolved as a trade based document to provide a uniform basis for the receipt of tenders (Skinner 1979) and has now been used as the communication channel to provide the information for cost estimating, is a document which high 'data' content, but, it is suggested, low signification within the context of estimating.

It may now be argued that situational relevance as explained includes the notion of practical relevance, and that the concept of situational relevance is the appropriate relevance concept to use in evaluation of information systems aimed at the evaluation of practically relevant information.

Once the idea of situational relevance is set forth, and the corresponding idea of significant situationally relevant information introduced, it is apparent that information systems aimed at providing the latter sort of information would be particularly desirable sorts of systems.

The intrinsic attractiveness of the notion of a system supplying such information is due to its capturing the essentials of the vague popular notion of practical relevance. Practically relevant information must be information that bears on one's concerns and that fits with a pre-existent body of knowledge. Practically relevant information must bear on one's actions: allowing one to predict the consequences of action and of inaction.

If one is interested in judging the performance of systems with respect to a logical, not a psychological, notion of practical relevance, then it is suggested that the concept of situational relevance is the one to use in evaluations.

While situational relevance is a strong concept in the requirements it would place on the designer of a system. To be successful such a system would have to do the equivalent of deciding for each item of information in its supply; "(a) whether it was directly situationally relevant for the particular person concerned; (b) whether, if not directly relevant it was indirectly relevant on the basis of other elements of the person's view of the world, and (c) whether, if directly or indirectly relevant, it was significant" (Wilson 1973). To do this it would require the equivalent of a complete representation of the person's view of the world, and of his concerns, as well as inductive and deductive logical capacities. This would require a complete theory of learning and understanding for the person concerned.

Foskett (1972) has suggested that relevant should be taken to mean "belonging to the field/subject/discourse delimited by the terms of the request, as established by the consensus of workers in the field"; while pertinence (termed significance by Wilson) should be taken to mean "adding new information to the store already in the mind of the user, which is useful to him in the work which prompted the request". These two will often be equivalent but not always. The question may be asked, is all the bill of quantities relevant but only some of it pertinent? Certainly in terms of value this has been proven not to be the case, (Horner et al 1986), (Moyles 1973), (Hardcastle et al 1988). This work is however inadequate to allow a conclusion to be drawn because of the use of interpretatively relevant information which may well be items of insignificant value.

Adopting this argument, pertinence is decided by the specific destination. Relevance by consensus or the "accepted view". Thus relevance is that which is the basis of an accepted paradigm, after Kuhn (1962) and Ziman (1968). In this sense it may be argued that the 'bill' is a paradigm (an accepted way of thinking) but is there not a need to identify 'pertinence' in order that the effectiveness of the bill as a communication document could be improved?

In this sense it may be argued that the SMM based bill of quantities is the accepted paradigm for the transfer of relevant information, but, that the pertinent (significant) information can only be determined by the individual, his purpose, and his stock of knowledge. The variations which occur in pertinence views can be seen in the statements of Walker (1974), Paterson (1977), Bishop (1966), Bennett (1985) and others. Relevant can then be taken to mean being part of the paradigm, or public knowledge, or consensus in a field whereas pertinence relates to the specific pattern of thought in a specific reader's mind (Schutz 1970).

Thus;

(14) $$I_1^2 = Q/([(f_1^2 \text{ form})(1-M)][1-D] + K_1^2) - R$$

and;

(20) $$Q_{TIM} = fF_{Sed}$$

Where $Q_{TIM}$ is the well defined question as determined by the imposed topical relevance, interpretive relevance and motivational relevance, which in turn is a function of the 'sedimentation of knowledge' of the estimator.

Then;

(21) $$I_1^2 = Q_{TIM}/([(f_1^2 \text{ form})(1-M][1-D + k_1^2) - R$$

Kemp (1974) confirms this view and notes that relevant documents and pertinent documents both have the quality of containing information related to the needs of the user. The important additional quality which distinguishes pertinent from relevant documents is that pertinent documents are those which he finds useful because they have a bearing on his particular situation, (Wilson 1973). Relevance of a particular document to a particular request is something which can be agreed by several people who are expert in the particular field of interest. Cooper (1973) argues that this is how relevance ought to be assessed when information systems are being tested. On the other hand, the pertinence of a particular document to a particular need is something which can be decided only by the person with the need. These views confirm those of Foskett (1972).

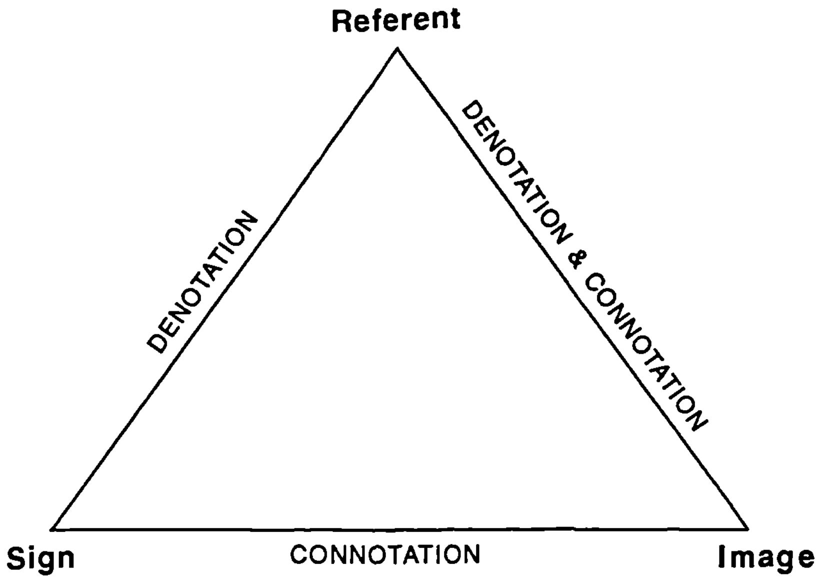
Cooper (1973), asserts that 'subjective utility', which is identical with pertinence as described here, is the principal valid means of determining the value of information systems.

He argues that in the 19th century, the philosophical school of thought called pragmatism developed suggesting that the meaning of an idea consists of the pragmatic consequences of the idea. Radical pragmatism of the 20th century argues that actions in the outer world, have exclusively practical aims, in particular aims to satisfy biological needs. In the fields of action, in manufacture, industry production and governance, pragmatic concepts are prevalent.

Cooper (1973) proposes that the true role of an information system is to provide information that has utility - information that helps to directly resolve given problems, that directly bears on given actions, and/or that directly fits into given concerns and interests. Thus, it is argued that relevance is not a proper measure for a true evaluation of an information system. A true measure should be utilitarian in nature.

It has been argued by Kemp (1972) that relevance and pertinence are two different qualities, one capable of public, objective assessment, and the other being capable only of private, subjective assessment. The contrast between the qualities of public and privateness in this pair of terms resembles similar contrasts between other pairs of terms from other fields concerned with the study of knowledge and its communication, e.g. denotation and connotation as used in relation to the psychology of learning. These other fields may therefore be useful sources of ideas which might lead to improved understanding of the nature of relevance and pertinence in particular and to practical improvements in information systems.

Kemp (1974) argues that anyone who studies the various fields of knowledge from which the pairs of *terms are drawn will come* across the 'triangle of meaning' as discussed by Ogden & Richards (1949), see figure 19 below. The three elements of meaning - the thing refered to (the referent); the sign used to refer to it; and the thoughts or mental image which the person has of it - are each placed at the corner of a triangle, and the sides represent the relations between these three elements. If one considers information requested and responses in terms of such triangles, it is obvious that an ideal response to a request would be an item of information which could be represented by a triangle congruent with that which represented the request. In the context of cost estimating there would be




**Triangle of Meaning**
**Figure 19.**

congruency between the information supplied by the design team and that required by the construction team and vice versa. These in themselves would have to be based on full awareness of needs and not simply on demands which may have been conditioned by the existing communication system.

A connection also exists between connotation and pertinence: both depend on associations (and implications) which are, or may be unique to an individual. Communication, including communication involving documents and information systems - will be assisted when both source (that is, the Quantity Surveyor/Estimator in the case of cost information communication) and receiver (Estimator/Quantity Surveyor) have connotations (as well as denotations) in common.

Kemp proposes that one of the factors which affects pertinence rather than relevance is prior knowledge. As noted by Foskett (1972), information of which the user is aware at the time may well be relevant but will by definition not be pertinent. This parallels the psychological perspectives taken by Schutz (1970). Availability of documents, ease of access and information also affects pertinence.

The mere existence of a need is not by itself sufficient to produce a request: for a request to be made, a need must exist and be recognised and the person with the need must also be capable of expressing it more or less accurately, and must state it. These additional circumstances do not necessarily or automatically follow, so that it may be that the supply of an item of information results in the recognition of the need for that information.

The phenomenon is especially important in relation to the communication abilities of an information system. The use of personality profiles might enable the recognition of matches between new information and information receivers who, on being supplied with that information are most likely to recognise its usefulness. As presently understood the existing paradigm is dictated by the Standard Method of Measurement. It is possible this could be developed by analysis of personality profiles, reflecting the previous background, experience of the individual and groups of individuals, (i.e. previous sedimentation).

They could also deal with 'personality' in a more psychological sense, by indicating the ability of the user to deal with large amounts of information, his ability to recognise new information, to synthesise it with existing information and so on.

The pertinence view or destination's knowledge view of relevance stresses the content of the file of the destination. The interest in people as the ultimate destinations in knowledge communication is of overriding importance. thus, "in the pertinence view of relevance, determining factors are the nature, structure and extent of one's stock of knowledge at hand, the process and sequence of its sedimentation and the process of the mind's selectivity", (Saracevic 1975), (compare Schutz 1970).

The destination's view of relevance attempts to incorporate all factors that enter into human relevance judgement. The stress is on judgement. One of these factors is the stock of knowledge at hand, which in turn, is the base of the pertinence view. Therefore, the destinations view does incorporate the pertinence view of relevance, but the latter is much more to the point. The pertinence view has a firmer base than the broad destinations view, because of a considerable number of philosophical and psychological investigations that have been devoted to the understanding of how we know what we know. These could be directly related to the pertinence view. "In comparison there has been a much smaller number of investigations on human judgement; thus the broad destinations view has little to relate to" Saracevic (1975).

Little work on the pertinence view of relevance has gone beyond providing a general framework for the view, either in the concept of information need or in the contrast between public and private knowledge. There has been no enumeration of the specific elements and relations that are a part of either framework. Therefore the view has only broad outlines - it is incomplete within these outlines. "This incompleteness provides an invitation for research" Saracevic (1975). However testing systems using measures or criteria as difficult to define as relevance is extremely difficult.

Information need can be considered as underlying a question in the sense of a desire to be furnished with unknown knowledge for use in a problem solving situation (e.g. cost estimating); the question is a verbalised (oral or written) representation of the need. Since the question as a representation may or may not necessarily correspond to the need it follows the document or (data) relevant to the query may not necessarily be appropriate to the information need. Adopting this hypothesis and using it in a proposal for testing methodology, Goffman and Newill (1966) called the property which assigned members of a file (e.g. documents) as answers to the question relevance; conversely the property that assigned members of a file to the information need was called pertinence.

Thus, relevance does not imply pertinence, nor does pertinence imply relevance. In other words there may be answers that are relevant but not pertinent, or pertinent but not relevant.

The debate concerned itself with objectivity/subjectivity of relevance. Two schools of thought were developed, best represented by Doyle (1963) and Cuadra (1964). In general Doyle viewed relevance as a subjective and elusive property that cannot serve as a criterion for any measures. Cuadra on the other hand conceded that relevance may be subjective but called for rigorous experimental observations upon which to base conclusions.

## 6.7 Completeness of Theories

Taking into account different elements and/or the nature of different relations in the communication of knowledge, the following views of relevance are identified, (after Saracevic 1975).

The destination's view of relevance which considers the human judgement on the relation between documents conveying information and a topic (question).

The pertinence or destination's knowledge view of relevance which considers the relation between the stock of knowledge at hand of a knower and subject knowledge or subject literature.

The pragmatic view of relevance which considers the relation between the immediate problem at hand of a user and the provided information, involving utility and preference as the base for interference.

The the subject knowledge view of relevance which considers the relation between the knowledge on or about the knowledge and a topic (question) on or about the subject.

The subjective literature view of relevance which is related to the subject knowledge view considers the relations between the subject and its representation, the literature and a topic (question) on the subject.

The logical view of relevance which is concerned with the nature of the inference between premises on a topic and conclusions from a subject or subject literature. Two views have emerged; the deductive inference view which considers the relation between premises and conclusions on the basis of logical consequence; and the probabilistic inference view which considers the relation among premises, information as evidence and conclusions on the basis of degree of confirmation or probabilities.

The systems view of relevance, which considers the contents of the file and/or the processes of a given information system and the relation to a subject or subject literature, a topic (question), or a user or users.

The following can be ascertained. Different views of relevance are not independent of each other. It seems that there exists an interlocking, interplaying cycle of the various systems of relevances (i.e. various systems of measures). Some systems may be considered as special cases or subsystems of other more general systems. There is no and there cannot be any one specific view of relevance, for there does not exist any one system of relevance in communication. Different systems of relevances may involve some different factors but they are coupled in such a way that they can hardly be considered without other systems of relevance. For instance the pragmatic view cannot be considered without involving the pertinence view or destination's view of relevance. None can be considered without subject knowledge view. Many practical problems in information systems and many cases of user dissatisfaction can now be explained as due to the existence of various systems of relevances.

Therefore when considering relevance in a specific sense, one should be quite careful to indicate the elements and the nature of the relations between elements that are being considered. Different names can be given to the considerations of specific different sets of elements or different relations. This was started with names of pertinence and logical relevance. However, it should always be realised that any specific consideration of relevance is tied in with systems of relevances. "A most significant advance in thinking on relevance will be achieved with the illumination of the interplay between these systems" (Saracevic 1975).

It is suggested that cost estimating as a decision making process is very much a function of knowledge, information and communication. Knowledge is a consequence of information and the process of interpreting this information. Further, information cannot be divorced from the communication process which dictates its structure, format and content. If we wish to improve the quality of estimating we should investigate the relationships among knowledge, information and communication.

# CHAPTER 7

# CONCLUSION AND RECOMMENDATIONS

## 7.1 Model Development

This work began with a review of previous literature which reported on investigations into estimating accuracy. This review demonstrated that there had been significant research in this area, much of it empirical and yet there had been little or no improvement in the estimating accuracy achieved by practitioners as a direct result of this work. It was demonstrated that there remained a significant factor in the estimating process which had received little attention from researchers. This factor was information and its role in the communication process. It is argued that as a consequence there exists no information model of the estimating process which would facilitate research into the context, role and impact of information on the estimating process.

In seeking to develop such a model it was possible to show design as an entropic process in which information is essential to ensure that the initial concept is transferred into form with minimum chaos and maximum understanding. Within design and particularly within the iterative appraisal stages there is an explicit need for information to feed the measurement operation which in turn allows evaluation of the proposed design to take place.

It was demonstrated that there exists a number of entropy equations which show that both entropy and information can be defined in terms of the same kinds of equations, namely probability of events occurring. However, these equations cannot be divorced from the fact that the information which is needed to describe an object is something on the part of the actor and has little to do with information 'inside' the object. As such while the equations are useful they are not operable as measures of information without prior definition of what constitutes information for the actor. As information used in the design process is inevitably an outcome of a communication process it was necessary to investigate this process, as it was observed that communication takes place when actor/provider and actor/receiver of information have a shared experience set.

In order to be able to arrive at this definition it was necessary to develop a technical model of the communication process and relate this to the design process. This was done and it was shown that the knowledge gain of an actor/receiver in the estimating process is not only a function of the information available (ideal minus missing information) to the actor/sender prior to communication but is also a function of distortion, the actor/senders applied knowledge and redundancy.

The configuration and content of the information which feeds this process was investigated by reference to previous investigators and it was clear that the lack of attention shown to information by investigators had resulted in much confusion as to what constituted information within the context of a major communication document, the bill of quantities. A review of the investigations demonstrating many differing perceptions as to what constitutes the information requirements of a bill of quantities.

As it is not possible to separate and measure information without reference to the actor/receiver it was therefore necessary to investigate how the knowledge of the receiver is accumulated and how this then impacts upon the need and demand for information. It was shown that the ability to obtain information is a function of the ability to identify the 'well defined question'. It was then shown that this ability is in major part a consequence of how the 'sedimentation of knowledge' of the actor/receiver has been built up, whether monothetically or polythetically. This biographical approach to the accumulation of knowledge influences the actor/receivers view as to what constitutes relevant information as reflected in the 'well defined question'.

In order to complete the information model it was then necessary to identify and explain the concept of relevance. This investigation revealed that relevance may be considered as three related concepts, topical relevance, interpretational relevance and motivational relevance.

This allowed the completion of the information model which links cost estimating with entropy, information and knowledge.

This model demonstrated that estimating accuracy is a function of the change in the estimators knowledge and therefore his uncertainty. This in turn comes about as a consequence of the information content of a message. This information is sought via the well defined question which is determined by the biographical position of the estimator, his sedimentation of knowledge, the manner in which this knowledge was accumulated (monothetic/polythetic) and the impact of topical, interpretational and motivational relevances. The quality of the response to this seeking is determined by the quality of the genesis material available (ideal minus missing), distortion, applied knowledge of the encoder and redundancy.

(4) $$E_{acc1} > E_{acc2} = f(I^2)$$

and

(21) $$I_1^2 = Q_{TIM}/([(f_1^2 form)(1-M)][1-D]+K_1^2) - R$$

## 7.2 Model Testing

It has been noted that theories are highly immune to falsification and that the period of theory acceptance is ended by the appearance of a better theory or a new explanatory technique. Further, a theory is not a hypothesis in need of confirmation, but the basis of an explanatory and predictive technique.

It is argued that the the theory encompassed in the information model which has been posited can be used for the investigation of the impact of information and knowledge upon the activity of cost estimating. Such investigations could address a number of issues which are identified as variables in the model. It therefore constitutes a paradigm which contains an ontology and associated "weltanschauung" which is distinct from that of the cost and resource based paradigms which have historically dominated investigation into cost estimating. The developed model can be viewed as a framework which can inform the processes of "normal science" identified by Kuhn (1962). Once a paradigm has been set up and a scientific field has grown up around that paradigm, there is an interval of "normal science". The activity of scientists during this period is termed "puzzle solving". It is possible to identify the specific aspects of the model which could be further defined by the application of the testing procedures associated with normal science.

While an attempt is made here to specify the puzzles to be solved no attempt is made to comprehensively identify the mechanisms to be used for their solution. This is a task which involves the extensive pursuit of normal science to elaborate the theory by exploitation of the empirical content of the paradigm. The puzzles are selected in accordance with the embedded ontology or Weltanschauung and empirical analysis will help to resolve them. However, some elaboration of the model has been carried out in the investigations reported in Appendix B and summarised here in Section 7.9.

## 7.3 Configuration

The entropy of a configuration can be defined by the sum of two terms, a positive one, equal to the entropy the aggregate would finally attain if left to itself (i.e. its classical entropy) and a negative term equal to the amount of information necessary to reconstruct the original configuration from equilibrium (complete chaos).

Uncertainty increases as 'particularity' and therefore opportunity for more configurations increases. Thus if one selects a message from a source of n messages, each selection is a 'configuration' characterised by a certain probability. In order to destroy the uncertainty the 'configuration' must not only be clearly transmitted, it must also be the correct choice of configuration to facilitate an understanding of the source. In a situation where the source itself can have a number of perspectives, the incorrect choice of perspective for subsequent configuration cannot supply the necessary information to destroy the uncertainty.

There are difficulties associated with this approach when one tries to extend it to situations other than the simplest. The difficulty is in defining what the elements of a configuration are and what is the set from which messages describing the construction of a configuration from chaos are selected? The information process which sees the transposition of the Concept through Form to Information Sorting, Encoding and Transmission in the shape of a Signal can be seen within the context of Cost Estimating. As such, the Signal so produced should be in a form which contains the appropriate information to facilitate the Cost Estimating process. Within the context of design and construction suggestions have been made as to what constitutes the elements of the configuration. It is argued that these elements require further definition.

A preliminary to further elaboration of the information model requires the classification of the information such that it becomes possible to quantify it. This is the 'configuration' of the information system. The configuration of the system is not only essential to the further successful development of the model, its creation cannot be be divorced from the processes which dictate its structure and which therefore constrain it to present knowledge structures. This is a particular problem when one is seeking to assess the impact of information on knowledge.

An attempt is made in Appendix B to identify the components of a configuration by reference to the perception of practitioners and undergraduates of information structured using the views of 'expert' commentators adopted within a framework defined by information science. The results of this investigation are contained in Appendix B and the summarised in Section 7.9.

### 7.4 Context

Communication of information only takes place within the context of a specific process and is a direct function of the experience base of the receiver and his associated knowledge base.

The communication process is concerned with the relationship which is set up between sender and receiver, e.g., that between the contracting team and the design team and their perceived objectives. In order to communicate information the message has not only to be received but also understood. Effective communication between the sender and the receiver results only when they share experience. An experience set is an ordered set of data elements and relations. This distinguishing operation depends on how the data is organised (configuration) for it is this organisation and the relevance of the data which will provide for effective communication.

A further problem is that of meaning. When attempting to communicate the receiver assumes that no information is being communicated if no recognisable patterns are being received and these patterns will not be recognisable if the pattern does not reflect the receivers experience set, and can be linked with his sedimentation of knowledge.

In the field of construction and in particular construction cost estimating, it is likely that the 'pattern' of contract documentation will be 'recognisable', but the extent to which it is recognisable will vary among documentation as a consequence of the proclivities of the 'encoders', the quantity and quality of information they are in receipt of and the quality, experience and ability of the receivers. This aspect of 'pattern' is investigated in Appendix B and the conclusions summarised in Section 7.9.

## 7.5 Sedimentation

The quality of the model is dependent on the ability of the modeller and the information he receives depends upon this contextual state. This ability being a function of the modeller's sedimentation of knowledge.

The impact of the 'lifeworld' position of the estimator upon choice of information for the pre-tender estimating function is also investigated in Appendix B by reference to the choices made by undergraduates and post-graduates and the consequence of that choice upon accuracy achieved. Again this investigation is summarised in Section 7.9.

Yet, this approach to investigation fails to address the query, how can one improve the communication process if one is restricted by the receivers current experience and thus his perception of what is relevant and what is needed?

If an attempt is to be made to identify the success and failures of the current approaches to communication of information for cost estimating in the design and construction processes then it is essential to consider how knowledge is accumulated and utilised. It is suggested that there is a significant need for major research in this area. This has not been investigated in this work.

It has been noted that experience is important in an estimators ability to estimate future costs of construction. yet no clear definition is provided as to what constitutes experience or what it is about experience that produces improvement in estimating accuracy.

It has been argued that the receptors sedimentation of knowledge which contributes to his experiential base is crucially important in determining whether communication of information is effective.

Further, there are two ways in which the mind may grasp the meaning of its own previous experiences. These are polythetically or monothetically.

The polythetic process of building up of the meaning of an experience may be reconstructed in memory and all the steps run through by which the meaning of the experience became constituted.

The results noted in previous investigations into estimating accuracy may reflect the impact when an estimator moves from a monothetic to a polythetic approach. Whether this results from the 'expertise' of the estimator at the monothetic stage or from the lack of relevant information to support the polythetic process is not clear and requires investigation.

It should also be determined whether or not the communication media used in construction, as a consequence of structure and configuration lends itself to the polythetic process at all, or whether because of inherent deficiencies, estimators revert to monothetic processes. Indeed, to what extent is the communication media reflective of the needs of the estimating process (monothetic or polythetic) and to what extent does it determine and condition the wants and demands of the estimators without adequately reflecting the needs of the process?

This is a crucial question for the distinctness of knowledge depends upon an ability to refer the monothetically grasped meaning of an element of knowledge to the polythetic steps by which such knowledge was acquired. The degree of plausibility of knowledge will be determinable according to how this knowledge was acquired by clear and distinct steps which can be polythetically reconstructed.

Important aspects of this process within the context of estimating must be the understanding and apprehension of the bill of quantity items and the resource costs which ultimately constitute the cost estimate. The ability of an estimator to take cognizance of these aspects must in part be determined by the documentation which communicates this information to him and the relationship of this documentation to the manner in which these resource costs were generated and recorded. To fail to make this contact is to fail to provide for understanding and apprehension. Consequentially one is left to suggest that estimating even at the tender stage is to a large extent a monothetic process, again this requires to be confirmed or refuted by puzzle solving through empirical analysis.

This essentially historical situation is the sedimentation of all previous experiences, and this "stock of knowledge at hand" is that in terms of which one may act at any moment, that through which one can interpret and experience the lifeworld.

All anticipations and plans refer to previous experiences now at hand, which enable one to weigh chances. But Schutz (1970) states that this is only half the story. What I am anticipating is one thing, the other , why I anticipate certain occurrences at all. It is only the first part of these dichotomies which is answered by reference to the stock of experiences at hand as the sediment of previous experiences. It is the second part of these dichotomies which refers to the systems of relevances by which man within his natural attitude in daily life is guided (Schutz 1970). The 'what' is investigated in Appendix B, however there still remains a need for extensive investigations into the 'why'.

Why does a particular attribute appeal to the estimators attention to such an extent that he makes it the theme of his interpreting activity? What makes the interpretation of this attribute at all a problem to him?

**7.6 Relevance**

The act of estimating is dependent upon the availability of information of the correct quantity, quality and type, the suitable formulation of that information and the application of suitable interpretive techniques.

The information content in a message is therefore a measure of the change in the observers knowledge and consequently his uncertainty. As noted in the previous chapter the relevance judgement of the receiver of information is a key element in his determination of the usefulness of information transmitted to him/her.

Starting at the broadest level of definition one might first ask 'is information perceived as relevant to the estimating process?' and 'does this perception vary as a consequence of the 'lifeworld' position of the estimator?' An attempt to answer these and associated questions is demonstrated in Appendix B with the conclusions summarised in Section 7.9.

In attempting to model the communication process in order to propose improvement in information transfer it is necessary to attempt to understand the components and interaction of knowledge acquisition, retention and utilisation. Different notions of relevance thus enter into the specification information systems.

As relevance can be looked at from different points of view, there results a particular problem in regard to any attempt to investigate the role of information within a communication process which has not previously been defined within the context of a suitable model. This is the case in regard to that cyclical and iterative process within which the activity of cost estimating takes place.

Topical Relevance is the first form of relevance: namely, that by virtue of which something is constituted as problematic in the midst of the unstructuralised field of unproblematic familiarity - and therewith the field into theme and horizon. Within the context of estimating the term 'dubious' refers to the doubtfulness of the impact of that attribute upon the value of the item (or the project).

It is the set of "actual interests" which itself depends on the autobiographical and situational circumstances of the individual that limit what is commonly called the level of investigation. Thus the autobiographical and situational circumstances of the estimators, whether they be quantity surveyors or contractors estimators is of particular interest as it determines that which is topically relevant.

If the doubtful attribute is now thematically given to the estimator for interpretation. Then it follows that in resolving this doubt he must now seek to grasp the meaning of what is now within the thematic kernel of his conceptual field. He must interpret it. This type of relevance based upon prior experience is different to that identified so far and may be termed interpretative relevance.

The importance of interpreting correctly consists in the fact that not only the means to be chosen but even the ends to be attained will depend upon such a diagnosis. The satisfactorily plausible degree of interpretation opens a relatively high subjective chance of meeting the situation efficiently by appropriate measures. This type of relevance has been termed motivational relevance. Thus causal relevancy can be easily translated into terms of motivational relevance and the adherent systems of interpretational relevance.

In more general terms, motivational relevances are sedimentations of previous experiences, once topically or interpretationally relevant, which led to a permanent habitual possession of knowledge, remaining dormant as long as the former topical relevances do not recur, but which become actualised if the "same" situation or a typically similar one recurs.

Thus $Q_{TIM}$ found in the model is the well defined question as determined by the imposed topical relevance, interpretive relevance and motivational relevance.

The whole area of knowledge accumulation and relevance definition within the context of cost estimating is a major theme requiring much application of research.

Relevance also impacts upon the concepts of information demands and information wants where Information Demands refers to the demands which may be vocal or written and made to an information system. In some cases information wants will be synonymous with demands. It may well be that estimators and quantity surveyors may be unaware of the availability of information to satisfy their needs or may assume its unavailability, thus may not consider it relevant. This also requires investigation.

Schutz (1970) notes that knowledge means not only explicit, clarified, well formulated insight, but also all forms of opinion and acceptance relating to a state of affairs as taken for granted. When conventions exist and principles are accepted as in the case of formalised contract documentation then it may be postulated that this documentation forms the framework for knowledge 'as taken for granted' and as such conditions the formulation of the 'question' which seeks information. Whether this is well defined is unclear. For the well defined question must reflect the needs of process (estimating) and where the 'as taken for granted' documentation leads to an incorrect formulation of the question, 'wants' may be expressed in the question but not 'needs'. This has been investigated in Appendix B and is summarised in Section 7.9.

### 7.7 Missing Information

While the concept of information in the medium of communication cannot be divorced from the situation of the receiver, his knowledge base (sedimentation) and contextual position the model clearly indicates that the comprehensiveness of coverage of information in the medium is a function of how much of the possible information is missing from the medium, how much of it is distorted and how much redundancy exists. It would seem reasonable to assume that this side of the equation could benefit from substantial investigation.

The Signal is initially a function of the concept transferred into form, The form being the Architect's interpretation of the Client's brief in terms of functional, spatial, environmental, physical, structural and aesthetic parameters. In the perfect world this form would contain maximum information in that the design is complete in concept and definition.

The quality of the Signal provided is however not only a function of the application of these aspects of knowledge but also of the other factors noted above, i.e. context and relevance.

The initial function which impacts upon the quality of the Signal is Form itself or in this case the extent to which Form is complete prior to the stages of Sorting, Encoding and Transmission. If this is perceived at the Sorting stage then an iterative process may ensue in which the Quantity Surveyor will attempt to tease out further information from the designer. If this is not obtained then this information may be construed as missing information, 'M'.

At the encoding stage the quantity surveyor who finds himself without adequate information with which to perform the encoding may use his professional judgement and knowledge to augment the information available to him. To do this is to mis-represent the Form and therefore to distort the Encoded Document, thus Noise begins to creep into the Signal.

A further type of Noise, 'D', at the encoding stage is that which occurs as a consequence of the loss of information which does exist at the Form stage but which is lost as a consequence of the formalised approach to aggregating information.

The themes of missing information and noise are both in need of much investigation as is there impact on the accuracy of estimating.

## 7.8 Redundancy

Finally, as the encoding is completed, the Signal is prepared for transmission. In part this is done by producing a Bill of Quantities which contains the full encoding together with the necessary phraseology to facilitate decoding by the Contractor. At this stage, while there will be no further noise likely to creep into the signal there is the possibility of a reduction in informativeness as a consequence of increasing redundancy 'R' and reducing significance.

Signification involves shared information; the more sharing the more redundancy. Thus redundancy is inevitable. Research should seek to increase the signification of the information contained by reducing redundancy.

## 7.9 Initial Investigations

Investigations in Appendix B confirmed that there is a consistent agreement among individuals from different experiential bases that information is a key factor in the make up of an expert and in particular the expert estimator..

These results identify the perceived importance of skills in the definition of an expert followed by experience, knowledge and an ability to manipulate and interpret information. They also demonstrated that differing experiential bases do not impact upon the choice of criterion. The criteria of 'identify information' and 'interpret and manipulate information' received scores which identify them as perceived contributors to the profile of an expert.

In terms of skills and the expert estimator and in regard to undergraduates it is seen that the criterion with the highest ranking is that of 'ability to identify information required'. This is followed by 'feel for the market' and 'ability to interpret and manipulate information to complete estimate'. Post-graduates do not identify the same criterion as most important in this case. In this sample it is 'ability to interpret and manipulate information to complete estimate'. This is followed by 'ability to apply experience', 'thoroughness and accuracy' and 'ability to identify information required'. It was clear from the responses given here that the 'ability to identify information required' is perceived by both undergraduates and post graduates as a key skill of the estimator.

In determining the most important factors to be considered when estimating construction prices undergraduates suggests that the criterion with significantly the highest ranking is that of 'construction quality and specification'. This is followed by 'building complexity', 'quality and quantity of information available' and 'type of building'. Post-graduates identify the same criterion as most important but with slightly lower score than the undergraduates. The profiles of responses are almost the same in both samples with the choice of the first five criteria only differing in the respective ranking of 'building complexity', ranked second by undergraduates and third by post-graduates and 'quality and quantity of information available' ranked third by undergraduates and second by post-graduates.

The above results indicate that when the ability to identify, interpret and manipulate information is identified as a possible input to the make up of an expert and in particular an expert estimator, both undergraduate quantity surveying students and post graduate construction management students will perceive it as an important input.

In investigating 'Information Chosen for Estimating', the results shown indicate the pre-eminence of the quantity factor

'Gross Floor Area' as the major information facet perceived as important by both undergraduates and post graduates. In the sample of undergraduates this is followed by 'Number of Storey's', 'Function' and 'Location' after which the relative hierarchy of choice is much less definite. In the sample of post graduates 'Gross Floor Area' is followed by 'Location', 'Type of Contract', Foundation Type' and 'Number of Storeys'. The profile of post graduate responses is much less sharp than that of the undergraduate sample.

In investigating the 'Impact of Information upon Estimating', the results demonstrate that the level of accuracy achieved varies across the groups. The least accurate estimates being provided by the undergraduate quantity surveyors followed by the post-graduates and then by a sub-group of the post graduates, the post-graduate quantity surveyors (eight in number). The undergraduate result is however distorted by a single apparent rogue estimate by one of the sample. The figures for all groups compare favourably with those obtained by Morrison and Stevens (1981) in their survey of estimates at the tender stage from seven quantity surveying offices, (mean deviation 9.81%, standard deviation 13.14%).

The results differ from those found by Skitmore (1986) in his investigation of expertise in estimating, standard deviation 21.31% taken around a mean error of 10.51%. It is argued here that a significant contributory factor to the difference in results achieved in the projects is in the choice and supply by the investigator of appropriate information for use as a data source. This would appear to confirm that the identification of relevant information is a significant factor in the achievement of estimating accuracy. Indeed it may also be argued that this activity is the most significant activity in the estimating process.

It should also be noted that in all groups, there is a drift away from the actual estimate as more data is supplied. This is not the case with the undergraduate group when the rogue estimate is removed. In the case of post graduates (quantity surveyors and others) and the post graduate quantity surveyors alone there is a reduction in the standard deviation, suggesting a growing consensus. The drift away from the actual estimate as more data is supplied may also be explained by acknowledging that in having relevant information to hand in the form of the five historical projects, the additional data relating to the proposed project does not constitute information in that it is not contributing to the knowledge of the estimators.

In seeking to determine the pragmatic perception of the adequacy of the bill of quantities as a communication document across different samples with different experiential bases it was shown that there is substantial satisfaction in all sample groups in regard to; adequacy of information, ease of understanding, its ability to truly represent the work and its cost.

In investigating the importance of information facets it was shown that in regard to All Measured Work the single information facet which is considered to be of primary importance to the estimating process by all sample groups is the materials description. It was also noted that while the artefact aspect (material) is of primary importance, it is perceived that the description of the dynamic aspects (i.e. labour, plant and overheads), in total attracts a weighting approximately equal to that of the material facet. While the balance of perceived importance does not change as the question focuses on the specific sections of concrete and woodwork there is a recognition of the importance of plant to the concreting operation as this facet is rated more highly in this type of work than in woodwork by all sample groups. The importance of the labour facet moves in the opposite direction. The different experiential base of the samples not producing different profiles of response.

In the context of the Material Facet of All Measured Work the outstandingly important attribute is quantity. This is also reflected in the responses to the investigations of Concrete and Woodwork. These values are considerably more than those allocated to the second attributes and subsequent attributes. An attempt was made to group attributes according to whether their primary cost influence was upon the artefact or dynamic aspects of cost. This breakdown produced a profile whereby those attributes which contribute to the determination of artefact costs were very dominant while those attributes which contribute to the dynamic aspects of cost were considerably less in value.

This also revealed that in all cases the Quantity Surveyors allocated greater importance than the undergraduates or Estimators to the artefact attributes and less importance to the dynamic attributes. This is particularly highlighted in regard to the quantity attribute with the clearest distinction being found in regard to Concrete Work.

As in the Material facet above it is the quantity attribute which is dominant within the labour facet. This is particularly so among the sample of Quantity Surveyors. This is followed by the Operation facet which is clearly placed as the second most important facet. It can also be seen that in comparing the importance of attributes to the facets of Labour and Materials, there is a distinct change in balance of importance.

Within the labour facet there is an increased importance of the attributes of operation, location and element with a comparative decrease in importance of form, generic name and product name. When an attempt is made to group attributes according to whether they be artefact or dynamic based the value given to the artefact based attributes reduces considerably from material to labour for all work sections while the dynamic attributes increase under the same conditions. It can be seen that for all types of the work the estimators rate the quantity of labour factor lower than do the quantity surveyors. This was reflected in comments made by the estimator respondents to the investigator which noted that the inclusion of a quantity of labour attribute within the bill of quantities was not reasonable. This suggested that their preference was to have the information available to them which would allow them to quantify labour. Thus the attributes element, form, operation and location were particularly important in Concrete Work. The analysis of results of the investigations into the plant and overheads facets and attributes produced results which paralleled those of the labour facet.

It is clear from the above that when considering information at the 'Facet' level of definition there is substantial agreement among Quantity Surveyors and Estimators as to what the hierarchy of importance is. It is also clear that this agreement breaks down at the 'Attribute' level of definition. This suggests that an assumption that Quantity Surveyors and Estimators share a perception of what constitutes 'information' becomes erroneous as the level of definition of information becomes more specific.

## 7.10 Recommendations for Further Work

It has been possible to develop an information model which links cost estimating with entropy, information and knowledge. This model identifies the components and as such reveals areas for further investigation via 'normal research'. It is argued that benefits would be obtained through the application of empirical research techniques to the identification of those features which constitute the 'well defined question', i.e. those factors which fall within the definition of topical, interpretational and motivational relevance. It would also be informative to determine the extent to which these definitions are common or otherwise among the various actors in the communication process. Linked with these themes would be the investigation of the extent to which the biographical position of the actor and the associated sedimentation of knowledge dictates the preference for information as revealed through the various types of relevance. The above would provide a scientific analysis of the left hand side of the model which would then allow the investigation of the right hand side of the model to determine the extent to which the present communication mechanisms satisfy the information needs and demands of the actors in the process. Aspects to be determined include the extent to which information is missing or distorted, the role of applied knowledge in compensating for these deficiencies and the effect of redundancy on the quality of communication.

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# APPENDIX A

# EXPERIMENTAL APPROACH

## A.1 Method

Avramescu (1980) has noted the path of scientific research as "organised observations, statistical surveys, empiric relations and laws, search for analogue or similar processes based on a verified theory, assimilation with well fitting models which offer corresponding solutions, interpretation and application of results". While Faibisoff & Ely (1976) note, "The methodology used to determine information needs is the same as that used in social science research. Such tools and techniques as questionnaires, interviews, diaries, observation and analysis of existing data and experiments have the same limitations in user studies as they have in social science research, mainly, that one can only infer from the user's behaviour or words what is going on inside his head".

In 1971 Wood considered the strengths and limitations of each method used to study information needs, and suggested ways to improve these methods. He noted that while questionnaires and structured interviews are useful methods for producing quantifiable data, the standardised form of questionnaire cannot always reveal a users unique experience. The questionnaire leaves no way to determine the respondents mood at the time or to clarify ambiguous questions or answers. The interview though more expensive and time consuming can do these things.

A major weakness of questionnaires and interviews is that they cannot collect actual data on behaviour as it happens. To overcome this problem, Carter et al. (1967) recommend a structured interview in which the user is asked to concentrate only on a specified time or project. The resulting data then reflects the users active behaviour rather than his opinion.

"While questionnaires and interviews offer quantifiable data that can be compared over several populations and situations, they are not true measures of behaviour. Diaries and observation may provide more accurate indices of behaviour, though their results are often difficult to quantify. While the diary method should reveal actual behaviour, users often refuse to interrupt their work to record their actions", (Faibisoff and Ely 1976).

"Through observation the researcher can record the subject's behaviour without disturbance" (Faibisoff and Ely 1976). While this method can identify and determine information wants little knowledge of the subject's needs can be obtained from observation. Therefore it could be argued that "Studies of needs should concentrate on needs rather than on the system supplying the needs" (Faibisoff and Ely 1976).

As the terms 'information wants', 'information needs', 'information demands' and 'information requirements' are often interchanged "the need of the user is still not well enough known to permit one to completely formulate a design for an information system which will serve him", (Carter 1967).

However, Feitscher (1978) has suggested that in the same way in which the physical existence of electric current is demonstrated by its electrolytic, magnetic and thermal effects. By analogy, information content can be examined by its effects on human knowledge stored in the memory (information stores) and on human decisions (actions, behaviour). Once again however what this does not do is identify whether there exists a better source of information which could have a greater impact upon human decisions. It cannot do this because the impact of the information on the decision making is a consequence of the previous sedimentation which must therefore create a cycle in which that information which is sought is a reflection of that which has been previously accumulated.

It is recognised that due to its presuppositions Shannon's information theory is inapplicable to measuring the information content of documents. Any other theoretical approach to this question must be backed up by experiments to test the validity of the approach. In order to register the effects of information content on human memory it is necessary to model the process by means of a conceptual network. Only in this way can information content be examined and the hypothesis tested whether or not it will be possible - at least in the future - to measure information content. It is argued that the information model applicable to cost estimating has been developed.

## A.2 Early Experiments

In early experiments in information science Saracevic (1970) noted that "After relevance was selected as a criterion for performance but before testing there remained the problem of what instruments were to be used to measure the relevance of documents in relation to queries (or any other response demanding mechanism)". This problem is separate from other problems of methodology such as what and how many documents or records should be used and how they are to be processed. Some of the early tests used documents as instruments. But the problems associated with using people in recording relevance were not well known. The recording of relevance of documents in relation to queries eventually was considered to be a judgement, a preferential discriminatory response. However relevance and relevance judgement came to be considered as one and the same, the terms were used interchangeably. But as noted earlier they are different concepts, although a relation exists between relevance as a relation between a source and a destination in a communication process and relevance judgement as a response at a destination.

The lack of distinction resulted in confusion. Saracevic (1975) noted that "the great testing debate in the early and mid sixties in large part turned into a relevance debate. As a result relevance definitions proliferated by the dozen and a few hypotheses emerged. Eventually two schools of thought developed".

The first suggested that relevance is such an elusive and subjective property that it cannot serve as a criterion for performance testing, (Doyle 1963). The other school took the view that experimentation with relevance judgements should precede adoption or non-adoption of relevance as performance criterion (Cuadra 1964).

Saracevic (1970/2) noted that by the early and mid sixties the problems and significance of relevance were brought into the limelight through the activity of testing. Relevance was chosen as the criterion for performance measures. Many methodological problems were uncovered, especially in using people and their relevance judgements as the instruments for recording relevance at the destination. Through this activity a view of relevance emerged which considered relevance solely a property of a destination in a communication process. Relevance judgement was incorrectly equated with relevance.

The first experimental observation related to relevance was reported in 1961 and relevance experiments were reported to

1970. No significant experiments directly dealing with relevance have been identified after 1970.

The destinations view of relevance concentrated on factors that affect human relevance judgement. These factors affect relevance, but they are only one of the aspects that influences the measure of the effectiveness of the contact between a source and a destination in a communication process. One of the most obvious aspects not investigated was the effect of the limitations of human memory on relevance judgements.

By and large the test experiments ignored the issues of relevance judgement however Cuadra and Katter (1967) stated:

"... Most of the workers involved in system evaluation from 1953 to the *present have had relatively little* interest in relevance judgements per se. they have been interested in them primarily as a criterion by which to evaluate manual or computer based searches, or comparisons between them. These workers, of course, have been aware of disagreement among judges, but they have tended to consider such disagreement largely as an irritant, to be stamped out or bypassed as quickly as possible, rather than as a phenomenon worthy of interest in its own right".

Cuadra and Katter (1967) identified five major classes of 'relevance related variables as a working list of variables that may have an impact on relevance judgement: The Document, the Information Requirement Statement, the Judge, the Judgement Conditions and the Available Mode of Expression."

Rees, Schultz, et al.(1967) started by viewing the relevance judgement as a decision by a request formulator, which specified the relationship between a document and the request. It was considered that one property of the decision is that it is a matter of degree. Furthermore, it should be taken for granted that, as far as the user is concerned, his decision over a given document set at a given point in time is objective and absolute. The user is considered to be a relevance judge. It was hypothesised that the relevance judgement is reliable and objective - that is, it has a high degree of agreement (compared with general human agreements in judgemental situations) when performed under well defined restrictions. Specifically it was hypothesised that the relevance judgement is an objective instrument when a specific ordered and finite number of systems responses to a fully defined request are related by and for specific kinds of persons (users), performing specified functions in specified subject areas for a specified purpose, within a specified environment and at a certain limited point in time.

Relevance was then defined as relation between system responses and the user request, established by a judgement made by the user or his delegate, a relation which incorporates all the above restrictions and possibly others.

A different approach was taken by by O'Connor (1967) who noted that in practice there sometimes is disagreement among people competent to judge whether a given document is relevant to a specified request. He hypothesised that relevance disagreements occur because of differences interpretation of either requests or documents. The reasons for which a retrieval request may be differently interpreted were linked to unclear requests, specifically listed as: expressions which are ambiguous in the situation (semantic ambiguity); syntactic ambiguity; vagueness of scope of what is requested; differences in interpretation of the subject of the request; uncertainties related to what the requestor knows; how he will evaluate and interpret papers; and what his background and circumstances are. The reasons for disagreements about whether a particular document is of the kind specified by the request were specified as: unclear document; difference in interpretation of the subject of the document; the judges having different scientific or subject intuition, background and viewpoint; errors in interpretations; ignorance; differences on inference basis.

In summary the Cuadra/Katter hypothesis was concerned with detailed enumeration of variables which may affect relevance judgements and with classifying them into major classes. The Rees/Schultz hypothesis concentrated on stressing the variables and conditions under which the judgement would achieve a high degree of agreement. O'Connor concentrated on the reasons for relevance judgement disagreements and on conditions under which agreement in relevance judgement may or may not coincide - relating these conditions to unclearness. All three hypotheses are conceptually quite similar. All stress the importance of a variety of aspects of the background and actions of the judges, the documents being judged, the query, and the situation (conditions) in relation to which the judgement is being made.

Saracevic (1970/2) argued that the experimental studies were a step in the right direction and that "in conjunction with theory building and theory relating, the only way of creating knowledge on relevance".

The two largest and most comprehensive experiments were those reported by Rees and Schultz (1967) and Cuadra and Katter (1967). Cuadra and Katter performed fifteen experiments. One of the experiments examined the reactions of the judges to stylistic characteristics of articles and the elements of style underlying those reactions. It was found that judges did not separate their relevance judgements from stylistic considerations. The conclusion was that not only the content but also the style of an article significantly affected relevance judgement. This suggests an experimental approach in which a single document is used.

Rees and Schultz (1967) investigated the effect of various documents and various document representations on relevance ratings by various medically oriented groups, differing in their medical expertise. The findings of interest were as follows: documents themselves in the full text form, were the single most influential experimental variable in the experimental design; individual documents received significantly different ratings, both as a function of various groups of judges assigning ratings and as a function of the research stage at which the rating was assigned.

In another experiment Saracevic (1968, 1969) reported on the comparative changes in relevance judgements of users when three representations of the searchers were presented to the users in succession. The ability of users to recognise relevance from shorter formats in comparison to full *text judgement was* observed. Full text judgement provided the largest number of relevant answers. Titles were inadequate for recognising non relevant answers. This would suggest that within the limitations of time and concentration span an attempt should be made to use as comprehensive a description as possible.

Cuadra and Katter (1967) within the previous experiment explored the effect on relevance judgements of the degree of specificity of information contained in information requirement statements (queries). It was demonstrated that more information in a query would result in more agreement.

Rees and Schultz (1967) in their experiment investigated the effect of stages of knowledge on relevance judgements. The results suggested that as knowledge increases the searcher becomes more critical and demanding in rating articles as relevant.

The studies of Cuadra and Katter and Rees and Schultz touched upon the important subject of the environment within which relevance is considered. The findings were inconclusive. However, Saracevic (1975) suggested that the most fruitful experiments may be those that will examine the relevance and relevance judgement within the environment of the communicating process of the different classes of users.

### A.3 Methodological Instruments

In any experiment in any field, instruments used for recording do effect what is being recorded. Thus these instruments may be a subject of study. In relation to relevance judgement experiments, the instruments studied as variables were the available modes for the judges on or by which they could record their judgements. Measuring techniques from sociology and psychology have been used to study the effects of a variety of scales on relevance judgements, as reviewed below.

Cuadra and Katter (Katter 1968) examined the following: The amount of difference in judgement which results when judgement is recorded on a rating scale versus ranking of documents. The effects of the number and description of categories on a scale. The sensitivity of two different scale forms: a nine point category scale versus a magnitude ratio procedure. The findings were as follows: In the group where the nine point rating scale was used twice, there was 5% of reversal and in the group where a second time a ranking was used, the reversals were 16.5%. Thus the rating scale seems to affect a higher consistency and thus by itself may less distort the results. The judges using the two and four category scales were more uncertain about their judgement and expressed more difficulty in making the judgement. The judges using scales with six and eight categories were more certain about their judgement. The stronger and non comparative language, by which categories were defined to some extent affected the certainty of judgement. Thus if high certainty in judgement may be desired, it seems that a rating scale with many categories should be used. The judges using the category scale in judging documents (which were already judged once) had a much higher agreement with the original judgements. The utilisation of the magnitude ratio scale was confusing.

Rees and Schultz (1967) conducted a separate experiment within their study in which the use of an eleven point rating scale was compared with that of a ratio type scale. The ratio scale was one where to each pair of documents presented for judging, the judge assigned 100 points in accordance with his estimate of the ratio of the overall relevance of the two documents. In the same experiment, the re-testing reliability of both scales was investigated. After the sessions a slight majority of the judges felt that the ratio scale gave a better reflection of their estimates of relevance; on the question of ease of use preference, the opinions were evenly divided. For individual documents, the distribution of judgements was different between the two scales. The rating scale tended to skew the distribution of judgements for the same document by different judges into one direction. The ratio scale made the distribution more uniform, but neither produced a normal distribution of judgements. The rating scale tended to be concentrated around the end points for most documents. The reliability of judgements was as follows; using the rating scale, judges agreed with themselves in two sessions on 73% of judgements and on using the ratio scale on 88% of the judgements.

## A.4 Experiment Summaries

Documents or objects conveying information are, of all other variables, the major variable in relevance judgements. Though the most important of the factors that would affect relevance is the subject content of documents as related to the subject content of the query. Elements of style may be expected to affect relevance judgement and the more specific the subject content of a document, the more relevance agreement may be expected.

This supports the theory that views relevance as a relation between documents and a query, or more specifically, as a measure of the effective contact between a source and destination in a communication process, and since documents or any conveyors of information are provided by a source in a communication process, this confirms the involvement of a source in relevance judgement and also in relevance as a property of information.

The more the judges know about a query, the more agreement among judges on relevance judgements may be expected and the more stringent the judgement becomes.

Changes in experimental condition may introduce changes in judgements (Cuadra & Katter, Rees & Schultz). The more pressure existing in judgemental situations, the higher ratings of relevance (i.e. more relevant) may be expected. This supports the observation that "the more desperate a user is for information, the more relevant everything becomes."

Different kinds of scales (rating, ranking and ratio scales) may produce slightly different judgements. The more categories a rating scale has the more judges may be certain in their judgement.

It is not clear what types of scale are most reliable for use in recording relevance judgements though it seems that some form of ratio scale may have some advantage over other types of scale for reliability. On the scales tested judges may tend to agree with themselves over a short period of time with a high degree of agreement and people are intra reliable to a very high degree.

Regardless of the number of categories in a rating scale, it may be expected that the end points of the scale will be used most heavily.

The judgements of different judges on one and the same document do not tend to be normally distributed; the distribution of judgements may be expected to be skewed in one direction and not to be uniform.

Most significantly, although the ratings of the degree of relevance may be scattered, the relative position of documents as to their relevance, especially among the documents with high relevance may be expected to be remarkably consistent even among groups of judges with differences in subject education, (Cuadra & Katter, Rees & Schultz),

People as a variable were present to some extent in all other variables; thus the conclusions from other classes of variables should be taken into account. It may be expected that a greater subject knowledge on the part of a group of judges will produce a higher agreement on relevance judgement. Subject knowledge seems to be the most important factor affecting the relevance judgement as far as peoples characteristics are concerned. The greater the subject knowledge of a group, the more stringent their assessment. It may be expected that a professional or occupational involvement with the problem that resulted in the query will increase the agreement of relevance judgement among and between groups of both subject specialists.

The approach adopted here uses the questionnaire approach within the context of structured interviews with a range of discipline groups. Though time consuming it was believed that such an approach would minimise the possibilities of confusion occurring. The use of the diary and observation approaches was not considered feasible as it was unlikely that the sample populations would be willing to interrupt their work routine. A model task approach was also used to determine the impact of information on estimating accuracy. Ranking and ratio scales were used at different stages in the investigations. The ranking scale where the criteria could not in any way be considered as having a quantitative perspective and the ratio scale where the criteria could be considered as having a quantitative perspective, i.e. in the contribution to estimating accuracy.

# APPENDIX B

# INFORMATION IN ESTIMATING

## B.1 Information and Expertise

Investigations into the definition of an "expert" in estimating have been carried out by Skitmore (1986). In these investigations a structured interview approach was adopted with 12 practising quantity surveyors in 1984. This proved a useful exercise and a number of criteria were identified. The free response of the interviewees allowing diverse comment. Among the key factors identified in response to those questions pertinent to this research were the following:

**What is your definition of an expert?**

| | |
|---|---|
| Experience | 8 Responses |
| Knowledgeable in a particular field | 6 Responses |

**What is your definition of an expert estimator?**

| | |
|---|---|
| Someone with experience and who can evaluate market's effect on price | 10 Responses |
| Someone familiar with going prices and capable of storing them in head | 5 Responses |
| Someone with a good feel for the job | 4 Responses |
| Someone who can combine a period of time with a number of jobs done | 4 Responses |

**What skills does an expert estimator possess?**

| | |
|---|---|
| Ability to apply experience | 5 Responses |
| Possession of al information available | 4 Responses |
| Ability to assess information you have | 4 Responses |

**How long does it take to acquire the skills?**

| | |
|---|---|
| Time in one area and a number of jobs | 6 Responses |

**What are the most important factors to be considered when estimating construction prices?**

| | |
|---|---|
| Construction/quality/specification | 10 Responses |
| Type of job/building | 8 Responses |
| Location | 7 Responses |
| Client/budget/cost limit | 6 Responses |
| Building complexity/shape/size | 6 Responses |
| The architect | 5 Responses |
| The site | 4 Responses |

The above indicates those criteria which were identified by more than 25% of interviewees. However the particular approach to the interviews did not allow discrete responses and as such some confusion of terms may have occurred. None the less it was felt that the responses were sufficiently informative to allow the identification of a set of criteria which could then be used together with a ranking scale in interviews with undergraduate students and post graduate students (some of whom were practising surveyors). There remained the problem of lack of discreteness of the criteria but the advantage of using criteria previously identified as being important was thought to outweigh this disadvantage. To the main responses identified in the work of Skitmore (1986) were added two criteria not identified by any of the respondents in the previous investigation, but in view of the previous discussions in this work considered to be valid for inclusion. These criteria were: Can identify information required for the task; and Can interpret and manipulate information to complete task.

These criteria together with a rationalised set obtained from Skitmore (1986) were then used in an interview questionnaire (see Appendix C) which sought to determine the perceived relationship between expertise, knowledge and information. A total of fifteen final year quantity surveying undergraduates and twenty-seven postgraduate construction management students were interviewed.

### B.1.1 What is your definition of an expert?

This question sought to determine if there was a consistent or differential perspective of criteria among and between the sample chosen. It also sought to identify the extent to which knowledge and information are explicitly identified by these samples as being significant in the make up of an expert.

In regard to undergraduates it is seen in table 1 and in figure 20, that the criterion with significantly the highest ranking is that of 'highly developed skills applied to a particular field'. This is followed by 'experienced in a particular field' and then 'can interpret and manipulate information to complete task'. The criterion 'high level of intelligence' was scored lowest followed by 'has a good feel for the work involved'.

Post-graduates identify the same criterion as most important but with slightly lower score than the undergraduates. This is similarly followed by the same second ranked criterion as the undergraduates but in this case with a slightly higher score. The third and fourth ranked criterion are the same as identified by the undergraduates but with the positions reversed. The lowest ranked criterion is also the same as that noted in the undergraduate responses.

These results identify the perceived importance of skills in the definition of an expert followed by experience, knowledge and an ability to manipulate and interpret information. They also demonstrate that the differing experiential base of the two samples has not impacted upon the choice of criterion. The criteria of 'identify information' and 'interpret and manipulate information' were responses not noted in regard to this question by the sample used by Skitmore (1986) but were included here and have received scores which identify them as perceived contributors to the profile of an expert.

What is your definition of an expert?

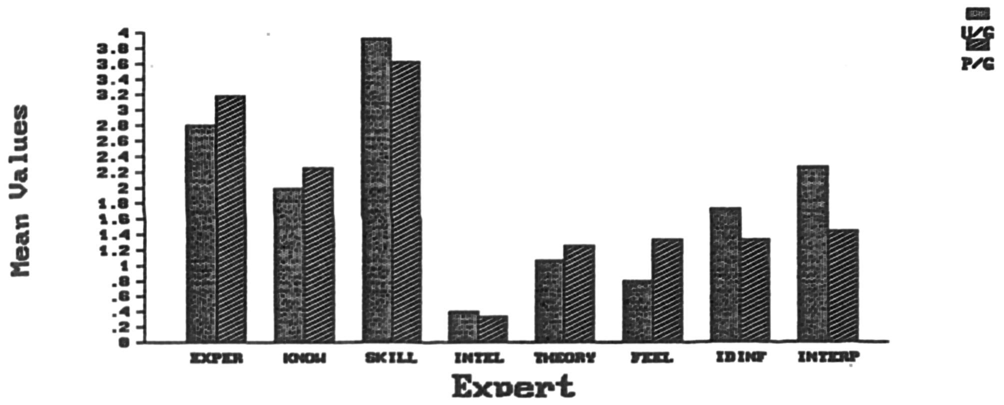



Figure 20.

| | U/G | P/G |
|---|---|---|
| Experienced in a particular field | 2.80 | 3.19 |
| Knowledgeable in a particular field | 2.00 | 2.26 |
| Highly developed skills to a particular field | 3.93 | 3.63 |
| High level of intelligence | 0.40 | 0.33 |
| Capable of applying theory to practice | 1.07 | 1.26 |
| Has a good feel for work involved | 0.80 | 1.33 |
| Can identify information required for the task | 1.73 | 1.33 |
| Can interpret and manipulate information | 2.27 | 1.44 |

Mean Values

Table 1.

The most important criterion identified here (skills) was noted by only three respondents in the interviews carried out by Skitmore (1986). This may reflect the difficulties which 'experts' may have in determining that they operate with a skill base which is inherent in there understanding of expertise, i.e. they have moved to that situation in which they have 'knowledge in hand' instead of 'knowledge at hand', see Chapter 5.5. The undergraduates as 'non-experts' give a high score to skills which may well parallel their approach to having knowledge at hand. It may be argued that the same cause underlies the high score achieved by 'interpretation and manipulation of information'. The disparate group of post graduates also identify skills as important and reflects their levels of knowledge

**B.1.2 What is your definition of an expert estimator?**

This question sought to determine if there was a consistent or differential perspective of criteria among and between the sample chosen. It also sought to identify the extent to which knowledge and information are explicitly identified by these samples as being significant in the make up of an expert estimator.

In regard to undergraduates it is seen in table 2 and in figure 21 that the criterion with significantly the highest ranking is that of 'experienced and can evaluate markets effect on price'. This is consistent with responses obtained by

What is your definition of an 'expert estimator'?

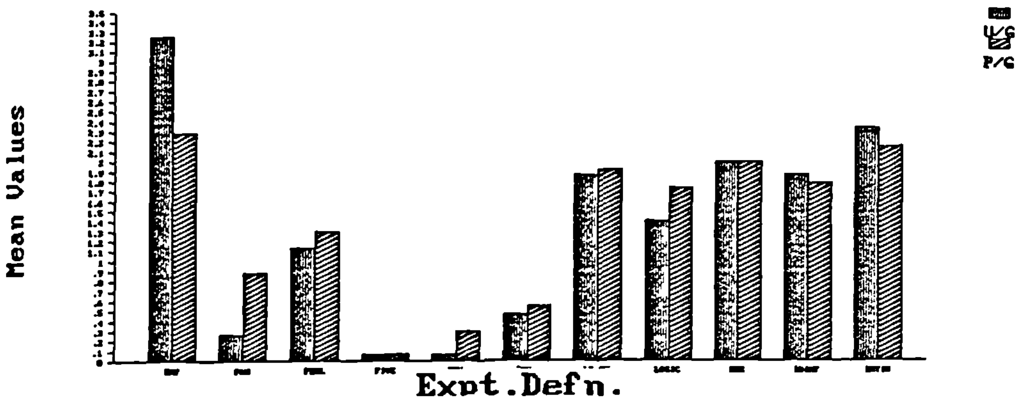



Figure 21.

| | U/G | P/G |
|---|---|---|
| Experienced and can evaluate markets effect on price | 3.27 | 2.30 |
| Familiar with going prices and can store them in head | 0.27 | 0.89 |
| Someone with a good feel for the job | 1.13 | 1.30 |
| Has worked on estimates for 1 to 5 years | 0.07 | 0.07 |
| Has worked on estimates for 6 to 10 years | 0.07 | 0.30 |
| Has worked on estimates for more than 10 years | 0.47 | 0.56 |
| Learns from previous jobs and performance levels | 1.87 | 1.93 |
| Works logically and thoroughly | 1.40 | 1.74 |
| Can see job as a whole at an early stage | 2.00 | 2.00 |
| Can identify information reqd. to complete estimate | 1.87 | 1.78 |
| Can interpret & manipulate informn. to complete estmt. | 2.33 | 2.15 |

Mean Values

Table 2.

Skitmore (1986) where this criterion received 10 out of a possible twelve responses. This is followed by 'can interpret and manipulate information to complete estimate' and 'learns from previous jobs and performance levels'. The criteria 'has worked on estimates for 1 to 5 years' scored lowest followed by 'has worked on estimates for 6 to 10 years'.

Post-graduates identify the same criterion as most important but with slightly lower score than the undergraduates. This is similarly followed by the same second ranked criterion as the undergraduates again with a slightly lower score. The third and fourth ranked criterion are the same as identified by the undergraduates but with the positions reversed. The lowest ranked criteria are also the same as that noted in the undergraduate responses.

The most important criterion identified here (experienced) was also noted as most important by respondents in the interviews carried out by Skitmore (1986). As above, the inclusion within the possible responses of criteria identifying information (not noted by the respondents of Skitmore 1986) resulted in those criteria attracting high scores ranking them second (interpretation and manipulation of information, 2.27 by undergraduates and 2.15 by post-graduates) and fifth (can identify information, 1.93 by undergraduates and 1.78 by post graduates).

The criterion of 'familiar with going prices' noted by five respondents in Skitmore's work scores low among both undergraduates (ranked ninth, 0.20) and post-graduates (ranked eighth, 0.89).

In the above questions it is clearly shown that information is perceived as an important input into the profile of the expert.

### B.1.3 What skills does an expert estimator possess?

This question sought to determine if there was a consistent or differential perspective of criteria among and between the sample chosen. It also sought to identify the extent to which knowledge and information are explicitly identified by these samples as being significant in the make up of an expert.

In regard to undergraduates it is seen in table 3 and in figure 22 that the criterion with the highest ranking is that of 'ability to identify information required'. This is followed by 'feel for the market' and 'ability to interpret and manipulate information to complete estimate'. The criterion 'analytical brain and numeracy' scored lowest followed by 'intuition and flair' and 'knowledge of labour and material prices'.

Post-graduates do not identify the same criterion as most important. In this sample it is 'ability to interpret and manipulate information to complete estimate'. This is followed

What skills does an expert estimator possess?

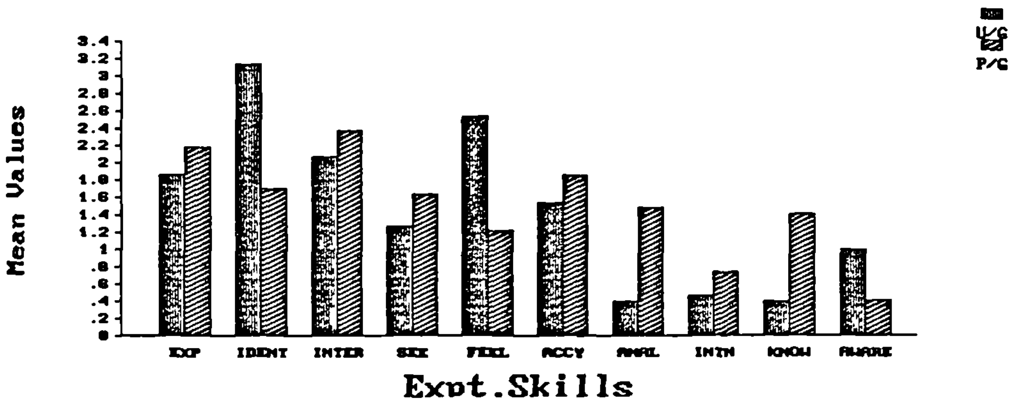



Figure 22.

| | U/G | P/G |
|---|---|---|
| Ability to apply experience | 1.87 | 2.19 |
| Ability to identify information required | 3.13 | 1.70 |
| Ability to interpret and manipulate information to complete estimate | 2.07 | 2.37 |
| Can see job as whole at an early stage | 1.27 | 1.63 |
| A feel for the market | 2.53 | 1.22 |
| Thoroughness and accuracy | 1.53 | 1.85 |
| Analytical brain and numeracy | 0.40 | 1.48 |
| Intuition and flair | 0.47 | 0.74 |
| Knowledge of labour and material prices | 0.40 | 1.41 |
| Awareness of client requirements | 1.00 | 0.41 |

Mean Values

Table 3.

by 'ability to apply experience', 'thoroughness and accuracy' and 'ability to identify information required'. Three of the first four ranked criteria are the same in each sample and two of these relate specifically to experience, i.e. 'ability to identify information required', ranked first and fourth and 'ability to interpret and manipulate information to complete estimate', ranked third and first. In the interviews carried out by Skitmore (1986) in regard to skills the response 'possession of all information available' occurred four times as did the response 'ability to assess all information you have'. The most common response was 'ability to apply experience' which occurred five times. It is clear from the responses given here that the 'ability to identify information required' is perceived by both undergraduates and post graduates as a key skill of the estimator. There exists a difference in profile produced by the two sample groups with a more definite discreteness discernible in the responses of the undergraduates.

### B.1.4 What are the most important factors to be considered when estimating construction prices?

This question sought to determine if there was a consistent or differential perspective of factors among and between the sample chosen. It also sought to identify those facets of information which could then be used later in an estimating exercise.

In regard to undergraduates it is seen in table 4 and in figure 23 that the criterion with significantly the highest

**What in your opinion are the most important factors to be considered in estimating construction prices?**

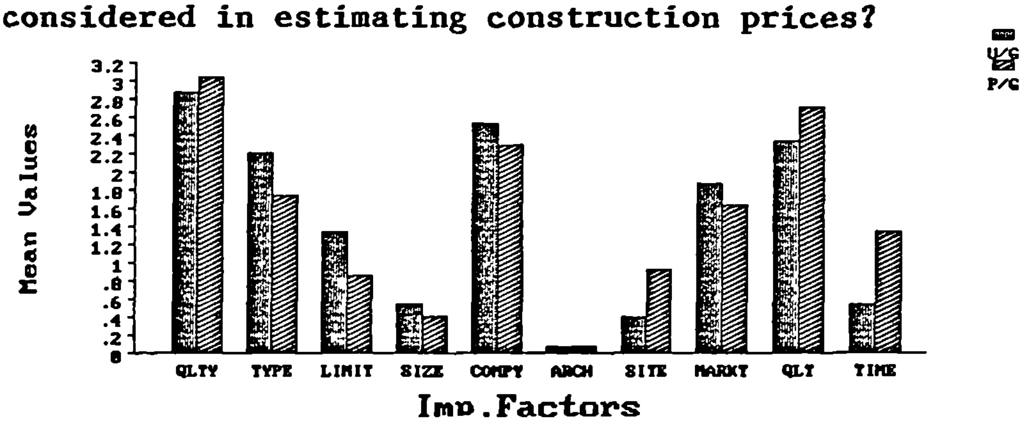



**Figure 23.**

| | U/G | P/G |
|---|---|---|
| Construction quality and specification | 2.87 | 3.04 |
| Type of building | 2.20 | 1.74 |
| Client budget or cost limit | 1.33 | 0.85 |
| Building size | 0.53 | 0.41 |
| Building complexity | 2.53 | 2.30 |
| The architect | 0.07 | 0.07 |
| The site | 0.40 | 0.93 |
| Market level | 1.87 | 1.63 |
| Quality and quantity of information available | 2.33 | 2.70 |
| Timing of scheme | 0.53 | 1.33 |

**Mean Values**

**Table 4.**

ranking is that of 'construction quality and specification'. This is followed by 'building complexity', 'quality and quantity of information available' and 'type of building'. The criterion 'the architect' scored lowest followed by 'the site'.

Post-graduates identify the same criterion as most important but with slightly lower score than the undergraduates. The second ranked criterion is 'quality and quantity of information available' followed by 'building complexity' then 'type of building'. The lowest ranked criterion is the same as that noted in the undergraduate responses.

The profiles of responses are almost the same in both samples with the choice of the first five criteria only differing in the respective ranking of 'building complexity', ranked second by undergraduates and third by post-graduates and 'quality and quantity of information available' ranked third by undergraduates and second by post-graduates.

The most important criterion noted here 'construction quality and specification' was also noted as most important by respondents in the interviews carried out by Skitmore (1986).

Some differences in choice of criteria appear from those identified in the work of Skitmore (1986). In relation to 'client budget or cost limit' this received six out of twelve possible responses in the work of Skitmore and thus suggested its importance, while it was ranked only sixth by undergraduates and eighth by post-graduates. A further difference appeared in relation to the criterion of 'type level of information available' this received only two out of twelve possible responses in the work of Skitmore which suggested its lack of importance, while 'quality and quantity of information available' was ranked third by undergraduates and second by post-graduates. Once again it should be noted that the criterion related to information is perceived by both undergraduates and post graduates as important to estimating.

**B.1.5 How well do you expect to do in the estimating task?**

This question sought to determine if there was a consistent or differential perspective of estimating accuracy among and between the sample chosen. It also allowed comparison with those figures achieved by Skitmore (1986).

Among the undergraduates none believed they could estimate within + or - 5% while only two believed they do so within + or - 10%. Four believed they could do so within + or - 15%, four within + or - 20%, one within + or - 25%, two within + or - 30% and two at greater than 30%.

Among the post-graduates three believed they could estimate within + or - 5% while ten believed they do so within + or - 10%. Four believed they could do so within + or - 15%, five

**How well do you expect to do on this estimating task?**

| | U/G | P/G |
|---|---|---|
| + or - 5% | 7 | 11 |
| + or - 10% | 13 | 36 |
| + or - 15% | 27 | 15 |
| + or - 20% | 27 | 19 |
| + or - 25% | 7 | 15 |
| + or - 30% | 13 | 0 |
| greater than + or - 30% | 7 | 4 |

**% Values**

**Table 5.**

within + or - 20%, four within + or - 25%, none within + or - 30% and one at greater than 30%.

The above indicates an extremely cautious view by undergraduates of their ability to estimate accurately while the more optimistic responses of the post graduates is more consistent with results found by Skitmore (1986) in regard to experienced quantity surveyors. In this study three believed they could estimate to within + or - 5%, three within + or - 10%, two within 5% to 10% and one within 20%.

The above results, B.1.1 through to B.1.4 indicate that when the ability to identify, interpret and manipulate information is identified as a possible input to the make up of an expert and in particular an expert estimator, both undergraduate quantity surveying students and post graduate construction management students will perceive it as an important input.

In three of the investigations (B.1.1, B.1.2, and B.1.4) there is a consistency of profile between undergraduates and post graduates while in one (B.1.3), 'What skills does an expert estimator possess?', there is a difference of profile with undergraduates producing a more dispersed set of results in comparison to the postgraduates.

## B.2 Information Chosen for Estimating

### B.2.1 Project Level

This investigation sought to identify the information perceived as important to the estimating process. As above the criteria chosen were those identified by Skitmore (1986) as contributing to the process of estimating. The purpose in this exercise was to determine the perception of individuals of the importance of various information types to the estimating process. In this exercise 30 undergraduate and 18 post graduate students were used. This allows some assessment of the impact of differential experiential bases upon the choice of information, undergraduates, post graduates and practising quantity surveyors (Skitmore 1986) though a different investigative approach was used in the later case.

The results shown in figure 24 and table 6 indicate the pre-eminence of the quantity factor 'Gross Floor Area' as the major information facet perceived as important by both undergraduates and post graduates. In the sample of undergraduates this is followed by 'Number of Storey's', 'Function' and 'Location' after which the relative hierarchy of choice is much less definite. In the sample of post graduates 'Gross Floor Area' is followed by 'Location', 'Type of Contract', Foundation Type' and 'Number of Storeys'. The profile of post graduate responses is much less sharp than that of the undergraduate sample.

Importance of Information Facets to Estimating (1/Mean Value)

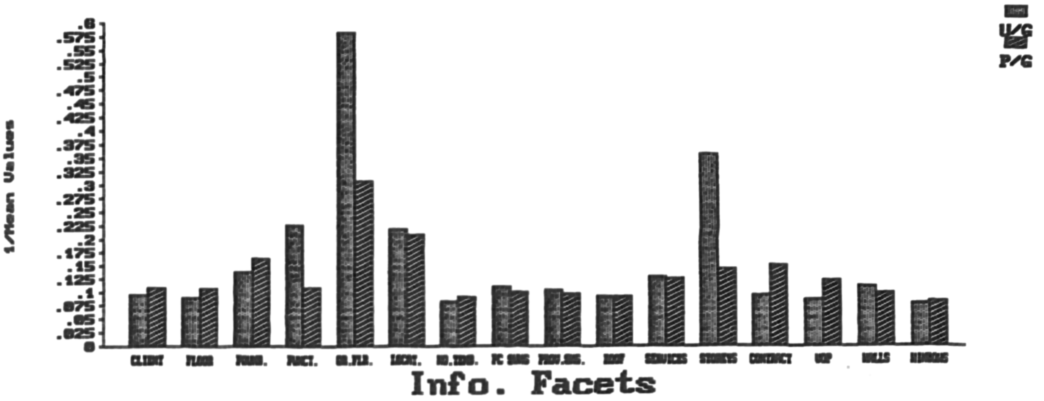



Figure 24.

| | | U/G | P/G |
|---|---|---|---|
| Client | _ | 0.10 | 0.11 |
| Floor Spec. | _ | 0.09 | 0.11 |
| Foundation Spec. | _ | 0.14 | 0.16 |
| Functional Unit | _ | 0.23 | 0.11 |
| Gross Floor Area | _ | 0.58 | 0.31 |
| Location | _ | 0.22 | 0.21 |
| No. of Tenderers | _ | 0.08 | 0.09 |
| PC Sums | _ | 0.11 | 0.10 |
| Provisional Sums | _ | 0.10 | 0.10 |
| Roof Spec. | _ | 0.09 | 0.09 |
| Services Spec. | _ | 0.13 | 0.13 |
| No. of Storeys | _ | 0.36 | 0.14 |
| Type of Contract | _ | 0.09 | 0.15 |
| VOP | _ | 0.09 | 0.12 |
| Walls Spec. | _ | 0.11 | 0.10 |
| Windows Spec. | _ | 0.08 | 0.08 |

Table 6.

The profile produced by the undergraduate sample is much closer to that suggested by the Quantity Surveyors in the estimating exercise carried out by Skitmore (1986). The experimental approach in this case was different but a cautiously taken simple 1/Mean Value approach used in those cases where the information facets occurred shows 'Gross Floor Area' to have the highest score with 1.44 followed by, 'Function' (0.24), 'Location' (0.22) and 'Number of Storey's' (0.20). In all three sample types other information facets are less clearly differentiated in importance.

### B.2.2 Item Level

This investigation sought to identify the information perceived as important to the estimating process as above but at the item level. In this case with no previously identified criteria list a set of criteria was determined after consideration of the work of Ranganathan (1967), Cunningham (1984) and construction experts (see Chapter 3). The purpose in this exercise was to determine the perception of individuals of the importance of various information types to the estimating process at the item level, (see Appendix D). In this exercise 15 undergraduate and 18 post graduate students were used. This allows some assessment of the impact of differential experiential bases upon the choice of information. The results given in figure 25 and table 7 indicate that while a similar profile of response is obtained for both

Importance of Information Facets to Estimating an Item (1/Mean)

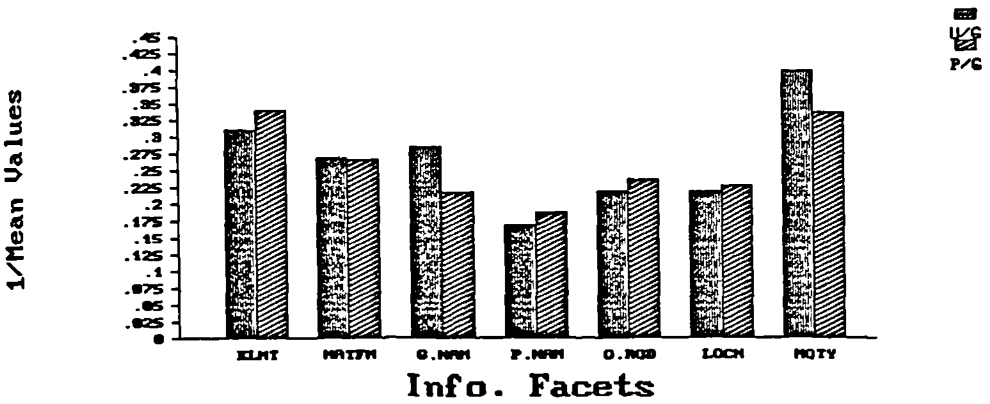



Figure 25.

| | U/G | P/G |
|---|---|---|
| Element (e.g. roof, floor) | 0.31 | 0.34 |
| Form of material (e.g. length, width) | 0.27 | 0.27 |
| Generic name (e.g. wallboard) | 0.29 | 0.22 |
| Product name (e.g. gyproc) | 0.17 | 0.19 |
| Operation required (e.g. laying, placing) | 0.22 | 0.24 |
| Location of material (e.g. 1st floor) | 0.22 | 0.23 |
| Quantity of material | 0.40 | 0.34 |

1/Mean Value

Table 7.

undergraduates and post graduates and while 'Quantity of Material' and 'Element' are perceived as most important there is no clear discrimination among the facets.

### B.3 Impact of Information upon Estimating

In an attempt to investigate further the impact of information chosen upon estimating an exercise was constructed in which interviewees were required to choose items of information and then to attempt to predict the price of a project. The methodology chosen was modelled on that used by Skitmore (1986) in his investigation of expertise in the estimating of project prices but in this case the interviewees were supplied with detailed historical data.

The methodology adopted required 14 undergraduates students and 18 post graduate students to request information from a defined set of information criteria supplied by the interviewer. In response an estimate was required of the price of that project and item.

#### B.3.1 Estimating a Project

The project chosen for the exercise was Sheltered Housing because of its simplicity of form and construction. The estimate was for that point in time at which the exercise took place and information was supplied in hard copy form. The interviewees were supplied with five similar historical

**Impact of Information Facets on Estimating Accuracy**

**Undergraduates**

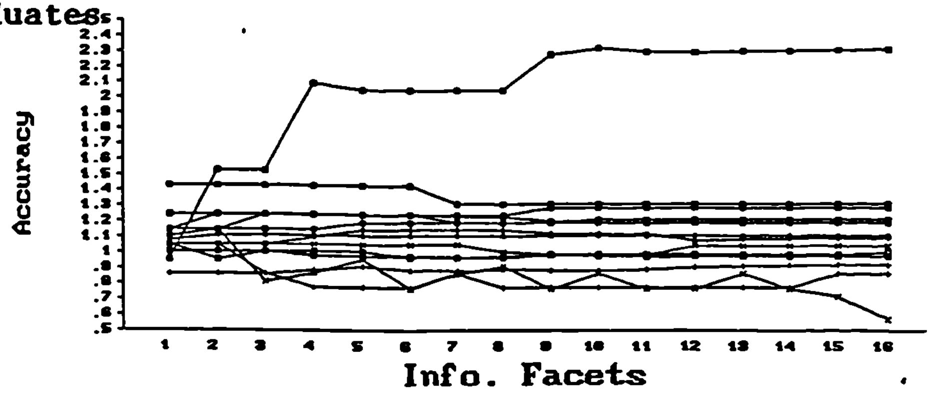



**Figure 26.**

**Impact of Information Facets on Estimating Accuracy**

**Post-Graduates**

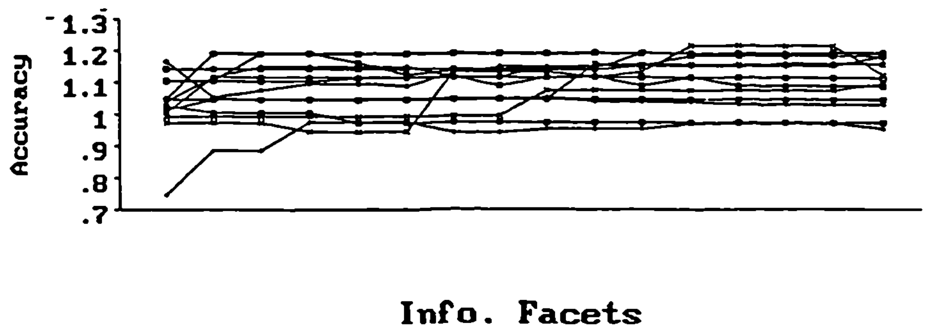



**Figure 27.**

| Estimate No. | U/G | | P/G | | QS.P/G | |
|---|---|---|---|---|---|---|
| | Mean | Std.Dev. | Mean | Std.Dev. | Mean | Std.Dev. |
| 1 | 1.09 | 0.13 | 1.03 | 0.09 | 1.01 | 0.12 |
| 2 | 1.14 | 0.14 | 1.04 | 0.09 | 1.02 | 0.07 |
| 3 | 1.11 | 0.21 | 1.05 | 0.10 | 1.02 | 0.07 |
| 4 | 1.15 | 0.32 | 1.06 | 0.10 | 1.05 | 0.08 |
| 5 | 1.17 | 0.31 | 1.06 | 0.10 | 1.05 | 0.08 |
| 6 | 1.15 | 0.32 | 1.05 | 0.10 | 1.05 | 0.08 |
| 7 | 1.15 | 0.30 | 1.06 | 0.10 | 1.07 | 0.09 |
| 8 | 1.14 | 0.31 | 1.08 | 0.08 | 1.07 | 0.09 |
| 9 | 1.15 | 0.37 | 1.09 | 0.07 | 1.08 | 0.09 |
| 10 | 1.16 | 0.38 | 1.09 | 0.07 | 1.07 | 0.08 |
| 11 | 1.15 | 0.38 | 1.08 | 0.09 | 1.09 | 0.10 |
| 12 | 1.15 | 0.38 | 1.10 | 0.08 | 1.09 | 0.09 |
| 13 | 1.16 | 0.37 | 1.10 | 0.08 | 1.09 | 0.09 |
| 14 | 1.16 | 0.38 | 1.10 | 0.08 | 1.09 | 0.10 |
| 15 | 1.16 | 0.37 | 1.10 | 0.08 | 1.09 | 0.10 |
| 16 | 1.15 | 0.35 | 1.10 | 0.08 | 1.08 | 0.09 |

Estimating Accuracy (Estimate/Actual)

Table 8.

projects updated in cost and broken down into those information facets noted earlier in B.2.1, (see Appendix E).

Interviewees were invited to estimate the cost of a single project at current prices. To aid them in this process they were suppled with information of 5 similar projects updated to current prices. The information comprised 16 attributes to describe the projects concerned and the interviewees were then in a position to request one attribute at a time from the interviewer which described the project to be estimated. At each stage an estimate was requested.

This exercise allowed the impact of each item of information upon the estimate to be assessed, the differential approach toward choice of information to be determined, the relative abilities of the interviewees to interpret the information to be noted.

The results shown above demonstrate that the level of accuracy achieved varies across the groups. The least accurate estimates being provided by the undergraduate quantity surveyors followed by the post-graduates and then by a sub-group of the post graduates, the post-graduate quantity surveyors (eight in number). The undergraduate result is however distorted by a single apparent rogue estimate by one of the sample, (see figure 26). When this rogue estimate is removed the values for the sample are; mean 1.06 and standard deviation 0.18. The figures for all groups compare favourably with those obtained by Morrison and Stevens (1981) in their survey of estimates at the tender stage from seven quantity surveying offices, (mean deviation 9.81%, standard deviation 13.14%). The results differ from those found by Skitmore (1986) in his investigation of expertise in estimating, standard deviation 21.31% taken around a mean error of 10.51%. It is argued here that a significant contributory factor to the difference in results achieved in the projects is in the choice and supply by the investigator of appropriate information (i.e. five similar projects) for use as a data source. This would appear to confirm that the identification of relevant information is a significant factor in the achievement of estimating accuracy. Indeed it may also be argued that this activity is the most significant activity in the estimating process. For while it may be understood that the post graduate quantity surveyors are the most experienced, the undergraduate quantity surveyors (excluding the rogue estimate) achieve a lower mean value, 1.06, though the standard deviation is greater at 0.18. Excluding the quantity surveyors, the remaining post graduates (ten in number) still achieve a highly acceptable mean value of 1.11 with a standard deviation of 0.09.

It should also be noted that in all groups, there is a drift away from the actual estimate as more data is supplied. This is not the case with the undergraduate group when the rogue estimate is removed. In the case of post graduates (quantity surveyors and others) and the post graduate quantity surveyors alone there is a reduction in the standard deviation, suggesting a growing consensus. The drift away from the actual estimate as more data is supplied may also be explained by acknowledging that in having relevant information to hand in the form of the five historical projects, the additional data relating to the proposed project does not constitute information in that it is not contributing to the knowledge of the estimators. They having already drawn logical conclusions as to the form of the project from the choice of historical projects. The choice of information by the participants confirmed the responses noted in 8.2.1. The dominant first choice information facet was Gross Floor Area (10 of fourteen undergraduates and 15 of eighteen post graduates). In choosing the second facet of information Number of Storeys was the most popular choice (7 undergraduates, 5 post graduates). Beyond the first two choices of information there was no clear preference for any particular facet. Among the final facets of information chosen Number of Tenderers appeared most commonly among undergraduates (6No.), while Client appeared most commonly among post graduates (5No.).

## B.4 Perceptions of Information Quality

It has been noted earlier that information may be perceived as containing either a semantic or a pragmatic truth. The latter being distinguished from the former in that while a statement may not contain the truth conditions to make it semantically true, if it is believed to be true, then for the individual it is pragmatically true. Such a condition in regard to someone searching and using information is likely to lead to a position whereby that person is unlikely to be aware of any possible deficiencies within the information source. A consequence of this condition is that information needs may not coincide with information requested.

As a preliminary to investigating the perception of the importance of information attributes to the estimating process it is worthwhile to identify the truth perceptions of those individuals. This was done in a series of preliminary questions to undergraduate quantity surveying students (33No.), practising quantity surveyors (75No.) and contractor's estimators (14No.). The choice of the three samples reveals the difference in perception which may/may not occur as a consequence of differing experiential bases, (quantity surveyors/estimators) and different stages of knowledge sedimentation (quantity surveyors/undergraduates). Other guides used as parameters of knowledge sedimentation were age of respondent, qualification of respondent, position in organisation, type of organisation and main area of activity.

### B.4.1 Adequacy of Information in the SMM6 Based Bill of Quantities

The responses to this question as seen in Table 9 were extremely positive toward the SMM based bill of quantities. The highest level of identification of 'less than adequate information ' was recorded by the undergraduates at 21.2%. The high general level of satisfaction was common across all of the parameters investigated, i.e., Age, Qualification, Position in Organisation, Type of Activity, Type of Organisation and Size of Organisation.

| | U/G | Contr. | Qty Surv. |
|---|---|---|---|
| More than adequate information? | 15.2 | 0 | 13.3 |
| Adequate information? | 63.6 | 85.7 | 76.0 |
| Less than adequate information? | 21.2 | 14.3 | 10.7 |

**% Values**

**Table 9**

### B.4.2 Attributes Deficient in Information

As a consequence of the profile of responses noted in B.4.1, there were few noted deficiencies in information.

Among the limited number of respondents who noted that the item descriptions were deficient in information the following pattern emerged. The most commonly occurring being, Construction Method, Location and Sequencing of Work. These are attributes which have for many years been identified by SMM scholars as being aspects in which the SMM based bill of quantities is deficient, (Bishop 1966). There was no

| | U/G (7No.) | Contr. (2No.) | Qty Surv. (9No.) |
|---|---|---|---|
| Material | 0 | 1 | 2 |
| Labour | 2 | 1 | 2 |
| Plant | 0 | 1 | 1 |
| Location | 3 | 2 | 8 |
| Assembly | 3 | 1 | 4 |
| Sequencing of Work | 4 | 2 | 4 |
| Construction Method | 6 | 2 | 6 |

**Table 10**

significant difference across all of the parameters investigated, i.e., Age, Qualification, Position in Organisation, Type of Activity, Type of Organisation and Size of Organisation.

### B.4.3 Ease of Understanding

In response to this question there was almost unanimous agreement among quantity surveyors and contractors estimators that the SMM based bill of quantities was easy to understand. However among the undergraduates 30.3 % of respondents did note that it was difficult to understand. This situation inevitably reflects their level of knowledge and suggests that while they may have knowledge at hand they do not have knowledge in hand. The high level of agreement among quantity surveyors and contractors estimators resulted in no significant difference across all of the parameters investigated, i.e., Age, Qualification, Position in Organisation, Type of Activity, Type of Organisation and Size of Organisation.

| | U/G | Contr. | Qty Surv. |
|---|---|---|---|
| Difficult to Understand? | 30.3 | 0 | 5.3 |
| Easy to to Understand? | 63.6 | 100.0 | 91.7 |
| Don't Know? | 6.1 | 0 | 4.0 |

**% Values**

**Table 11**

### B.4.4 True Representation of Work

The responses to this question were again very supportive of the SMM based bill of quantities. The quantity surveyors recorded the highest value belief in the bill of quantities as a true representation of work at 25.3% but in all three sample groups over 90% considered the document to be at least an almost true representation of the work. The high level of agreement resulted in no significant difference across all of the parameters investigated, i.e., Age, Qualification, Position in Organisation, Type of Activity, Type of Organisation and Size of Organisation.

| | U/G | Contr. | Qty Surv. |
|---|---|---|---|
| True Representation? | 3.0 | 0 | 25.3 |
| Almost True Representation? | 91.0 | 100.0 | 66.7 |
| Untrue Representation? | 3.0 | 0 | 8.0 |
| Don't know? | 3.0 | 0 | 0 |

**% Values**

**Table 12**

### B.4.5 True Cost of Items

The responses to this question were again very positive with over 90% of quantity surveyors and contractors demonstrating a belief that the bill of quantities contains true or almost true costs. As a group the undergraduates were less consistent with 15.2% indicating that the bill of quantities represented untrue costs. There was no significant difference across all of the parameters investigated, i.e., Age, Qualification, Position in Organisation, Type of Activity, Type of Organisation and Size of Organisation.

| | U/G | Contr. | Qty Surv. |
|---|---|---|---|
| True Costs? | 0 | 7.1 | 14.7 |
| Almost True Costs? | 81.8 | 92.9 | 80.0 |
| Untrue Costs? | 15.2 | 0 | 4.0 |
| Don't Know? | 3.0 | 0 | 1.3 |

**% Values**

**Table 13**

## B.5 Perception of Importance of Information to Estimating

It is noted above that there is substantial satisfaction among all respondents within the classifications investigated with the information supplied in the bill of quantities. In the development of an information model of the the estimating process it is necessary to be aware of this satisfaction despite the caveat of pragmatic truth. It therefore becomes necessary to further question the respondents in an effort to identify their perceptions of the importance to the estimating process of facets of information and their attributes. As not all of these attributes are always available within a bill of quantities such an investigation will provide confirmation or otherwise of the views noted in the previous investigation.

The structure of the questionnaire which was developed sought to initially classify information into four main facets which encompass the cost centres of a project. These facets reflect the artefact and dynamic aspects of a construction project and as such those aspects upon which information is required to be provided in either an explicit or implicit form. The same sample of individuals was used as above, undergraduate quantity surveying students (33No.), practising quantity surveyors (75No.) and contractor's estimators (14No.).

The facets chosen were;

Material
Labour
Plant
Overheads.

It was accepted however that the above facet definition was too broad and therefore inadequate as a mechanism for the determination of the criteria for the inclusion of data in a Bill of Quantities. Using the concepts previously outlined in regard to facet and attribute structures, a decision was made to identify a number of attributes of the above facets. The definition of these attributes would take account of the work of Ranganathan (1967) in that they would be sufficiently comprehensive to take account of the fundamental information categories of; personality, matter, energy, space and time. Furthermore the attribute definitions would seek to encompass those highly variable information concepts considered by 'construction experts' to be desirable in a Bill of Quantities, (see Chapter 3) and of the work of Cunningham (1984).

The attributes chosen were;

Element
Form
Generic Name
Proprietary Name
Operation
Location
Quantity.

The developed facet and attribute breakdown allowed a series of questions to be asked of both estimators and quantity surveyors. For this part of the investigation a ratio scale was chosen. The questions sought to determine views as to the relative importance of the information facets and attributes to the estimating process. Importance was understood to be reflected by the weighting given to each facet and subsequently to each attribute. The weightings being allocated from a possible sum of 100 available to each group of facets and attributes. Responses were sought in the context of the All Measured Work, the Concrete Work Section and the Woodwork Section of a bill of quantities.

### B.5.1 Facet Analysis

In regard to All Measured Work it is seen in table 14 and figures 28 to 30 that the single information facet which is considered to be of primary importance to the estimating process by all sample groups is the materials description, having been given a value of 42.58 by the undergraduates, 55.36 by the contractors estimators and 47.24 by the quantity surveyors. The level of consistency of values given is worthy of note. This response is indicative and reflective of the monetary importance of the artefact aspects of a building project and is very much in line with the views of those observers who have attempted to identify the cost breakdown in a Bill of Quantities in terms of material, labour, plant and overheads.

It should however also be noted that while the artefact aspect (material) is of primary importance, it is perceived that the description of the dynamic aspects (i.e. labour, plant and overheads), in total attracts a weighting of between 44.64 and 57.42, i.e. approximately equal to that of the material facet.

Yet, these are information facets which historically have not been explicitly included in a Bill of Quantities. It is of course accepted that a description of material input into a building carries with it an implicit operational aspect.

While the balance of perceived importance does not change as the question focuses on the specific sections of concrete and woodwork, (see tables 15, 16 and figures 31 to 36) there is a recognition of the importance of plant to the concreting operation as this facet is rated more highly in this type of work than in woodwork by all sample groups. The importance of the labour facet moves in the opposite direction.

Taking into account the large standard deviations which inevitably occur when using a ratio scale of 100 there is a high level of consistency among the sample groups. The most distinctive profile is produced by the Contractors Estimators where the material and labour facets dominate to a larger extent than in the other profiles with a consequent reduction in the importance of plant and overheads facets. In part this reflects comments made by five estimators that they would not expect to see information upon plant supplied in the bill of quantities. It may well also be a consequence of the different experiential base of the interviewees with the undergraduate quantity surveyors and the practitioner quantity surveyors having a different perspective.

**All Measured Work - Facets**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Material | 42.58 | 55.36 | 47.24 |
| Plant | 18.48 | 5.71 | 12.44 |
| Labour | 25.91 | 30.36 | 28.27 |
| Site Overheads | 13.03 | 7.86 | 12.12 |

**% Values**

**Table 14.**

**Concrete Work - Facets**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Material | 38.91 | 52.14 | 49.04 |
| Plant | 23.61 | 10.00 | 15.11 |
| Labour | 24.70 | 33.57 | 25.84 |
| Site Overheads | 13.33 | 4.29 | 9.87 |

**% Values**

**Table 15.**

**WoodWork - Facets**

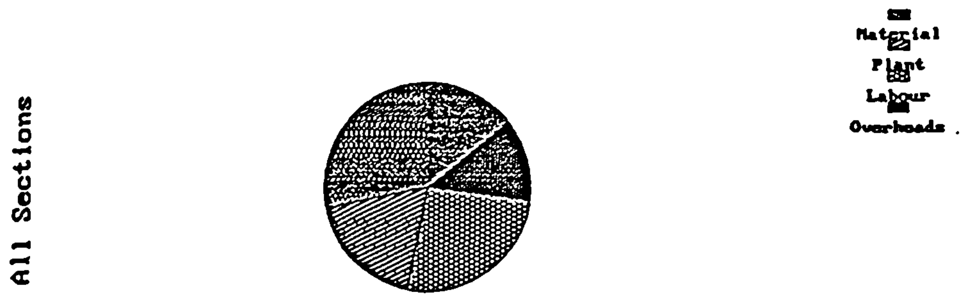
| | U/G | C/E | Q/S |
|---|---|---|---|
| Material | 41.06 | 57.86 | 50.60 |
| Plant | 15.36 | 2.50 | 10.55 |
| Labour | 30.45 | 35.00 | 29.13 |
| Site Overheads | 13.12 | 3.93 | 9.72 |

**% Values**

**Table 16.**

U/G is Undergraduate Responses
C/E is Contractors Estimators Responses
Q/S is Quantity Surveyors Responses

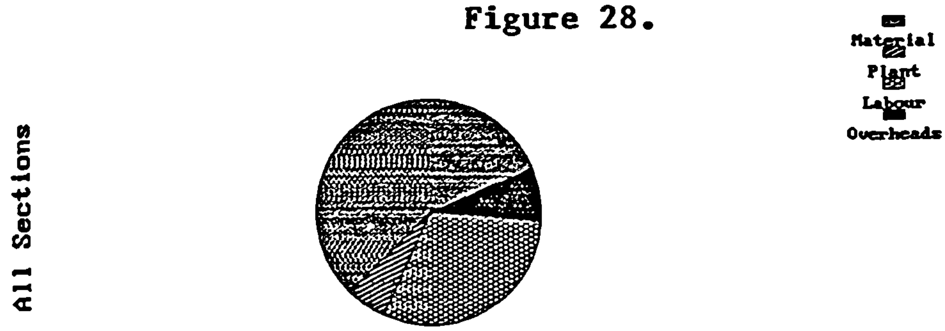
All Measured Work - Facet Analysis




Mean Values

Undergraduate Responses

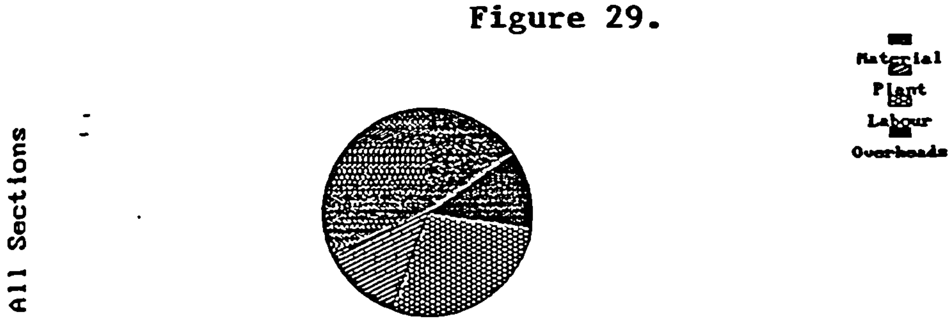
Figure 28.




Mean Values

Contractors Estimators Responses

Figure 29.

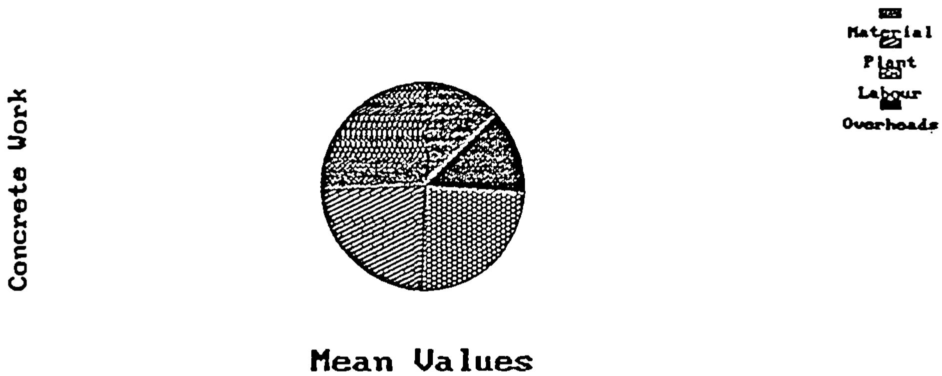



Mean Values

Quantity Surveyors Responses

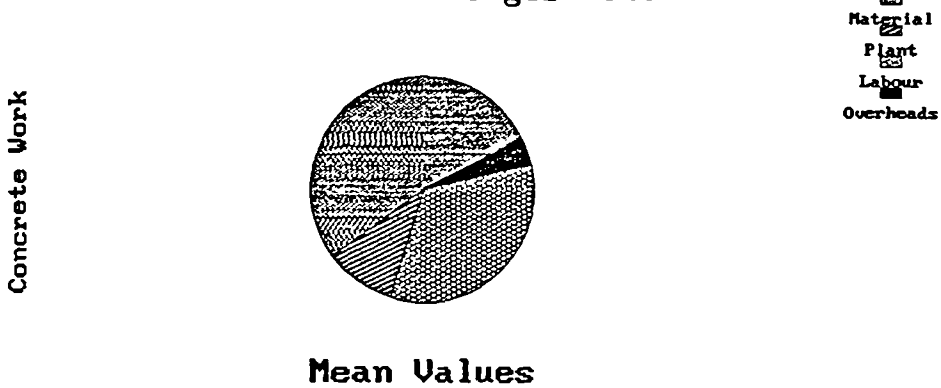
Figure 30

Concrete Work - Facet Analysis



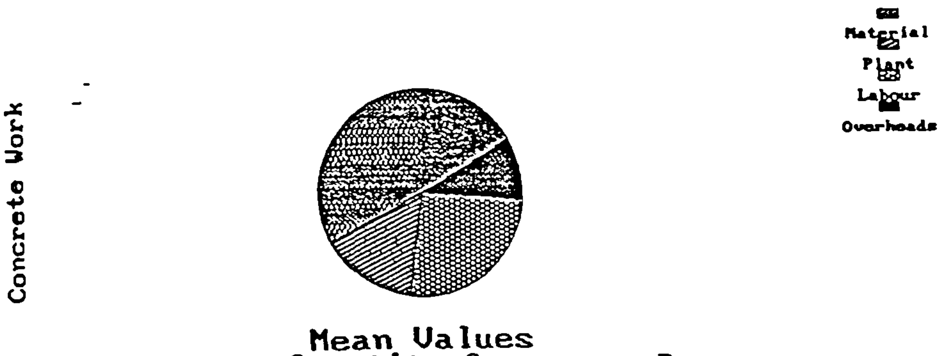

Undergraduate Responses

Figure 31.




Contractors Estimators Responses

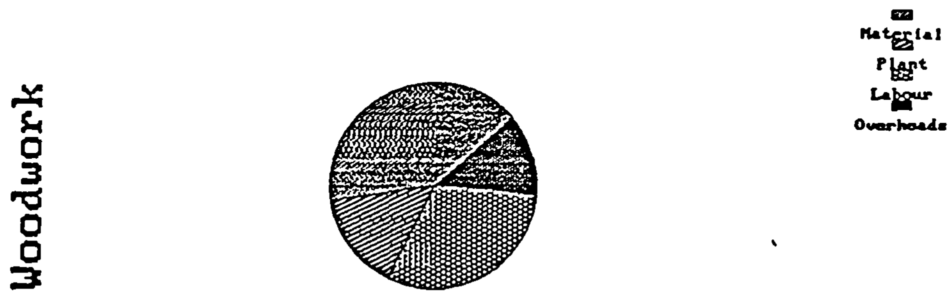
Figure 32.




Quantity Surveyors Responses

Figure 33.

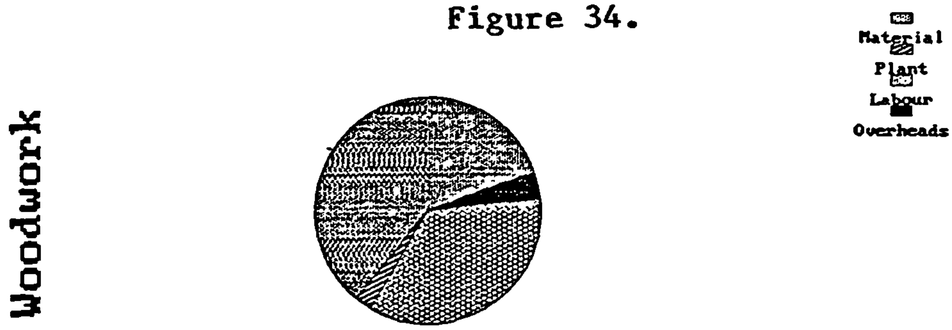
WoodWork - Facet Analysis




Mean Values

Undergraduate Responses

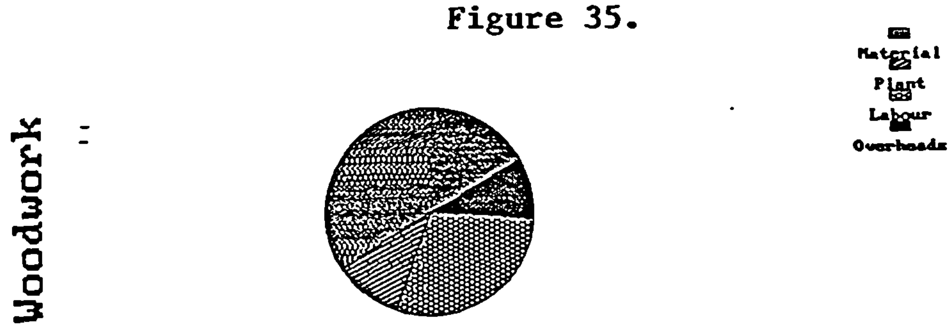
Figure 34.




Mean Values

Contractors Estimators Responses

Figure 35.




Mean Values

Quantity Surveyors Responses

Figure 36

### B.5.2 Attribute Analysis - Materials Facet

In an attempt to determine which attribute of each facet was considered to be the most important for the function of estimating an identical investigative approach was used, i.e. the respondents were asked to allocate 100 points across seven previously determined attributes. The allocation to reflect their perceptions of importance.

In the context of the Material Facet of All Measured Work the outstandingly important facet is quantity with a perceived importance ranging from a value of 25.57 (Estimators) to 31.28 (Quantity Surveyors). This is also reflected in the responses to the investigations of Concrete, 23.43 (Estimators) and 38.65 (Quantity Surveyors), and Woodwork, 23.94 (Undergraduates) and 34.61 (Quantity Surveyors). These values are considerably more than those allocated to the second attributes and subsequent attributes. It can also be seen that there is a preference by all groups for product name information over generic name information, and information on location and operation are considered to be among the least important.

Once the quantity attribute is removed, the hierarchical classification of the remaining attributes is not clear because of the similarity in values obtained. An attempt was therefore made to group attributes according to whether their primary cost influence was upon the artefact or dynamic aspects of cost, i.e. the insitu or operational aspects of the building project. For the material facet the artefact attributes were considered to be; quantity, form, generic name and product name. The dynamic attributes were considered to be location, element and operation. This breakdown produced a profile whereby those attributes which contribute to the determination of artefact costs were very dominant with values between 77.3 and 72.7 while those attributes which contribute to the dynamic aspects of cost had values between 27.3 and 22.7. While considerably less in value these values indicate a view that the attributes which influence dynamic aspects remain of substantial importance.

This also revealed that in all cases the Quantity Surveyors allocated greater importance than the undergraduates or Estimators to the artefact attributes and less importance to the dynamic attributes. This is particularly highlighted in regard to the quantity attribute with the clearest distinction being found in regard to Concrete Work, 23.43 (Estimators) compared to 38.65 (Quantity Surveyors), with the associated dynamic attributes values of 38.72 and 32.35.

In all cases Undergraduates and Estimators have profiles which are more similar than those of the Quantity Surveyors.

**All Measured Work - Material Attributes Analysis**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 13.39 | 12.36 | 9.23 |
| Form | 14.79 | 14.50 | 14.32 |
| Generic Name | 10.21 | 8.79 | 14.17 |
| Product Name | 11.82 | 17.71 | 13.65 |
| Operation | 12.45 | 11.50 | 10.84 |
| Location | 10.97 | 10.00 | 6.95 |
| Quantity | 26.06 | 25.57 | 31.28 |
| | % Values | | |

**Table 17.**

**Concrete Work - Material Attributes Analysis**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 18.33 | 14.93 | 9.65 |
| Form | 14.39 | 13.79 | 10.52 |
| Generic Name | 6.15 | 9.14 | 9.87 |
| Product Name | 5.21 | 15.21 | 8.60 |
| Operation | 15.45 | 13.79 | 11.33 |
| Location | 14.24 | 10.00 | 11.37 |
| Quantity | 26.21 | 23.431 | 38.65 |
| | **% Values** | | |

**Table 18.**

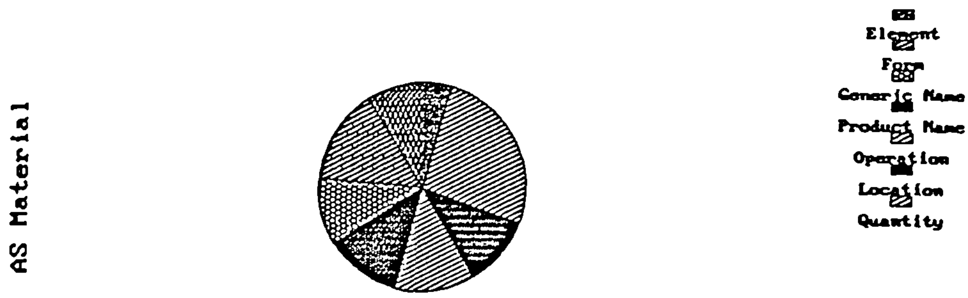
**WoodWork - Material Attributes Analysis**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 14.64 | 12.57 | 8.97 |
| Form | 17.97 | 13.07 | 14.08 |
| Generic Name | 8.30 | 9.50 | 12.31 |
| Product Name | 8.48 | 16.64 | 11.91 |
| Operation | 14.55 | 12.71 | 10.73 |
| Location | 12.55 | 10.71 | 7.49 |
| Quantity | 23.94 | 25.93 | 34.61 |
| | **% Values** | | |

**Table 19.**

U/G is Undergraduate Responses
C/E is Contractors Estimators Responses
Q/S is Quantity Surveyors Responses

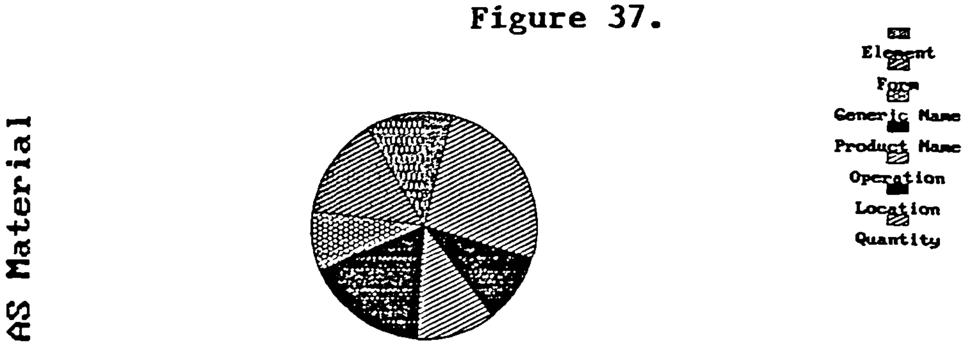
All Measured Work - Material Attributes Analysis




Mean Values

Undergraduate Responses

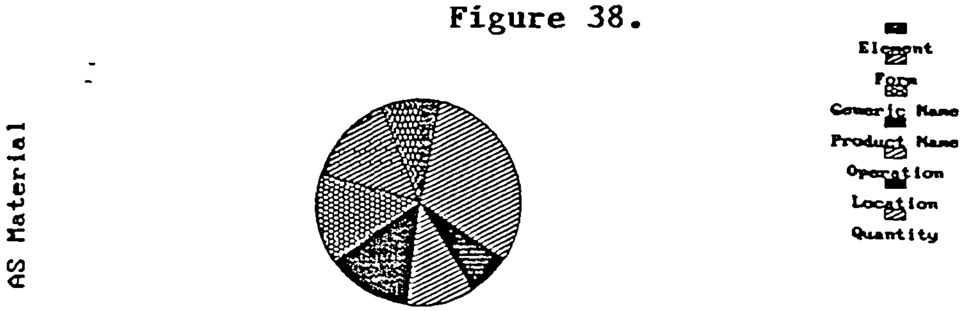
Figure 37.




Mean Values

Contractors Estimators Responses

Figure 38.

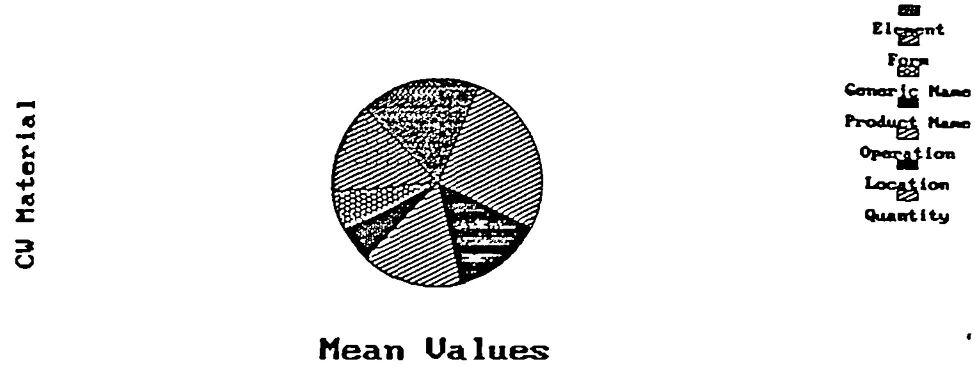



Mean Values

Quantity Surveyors Responses

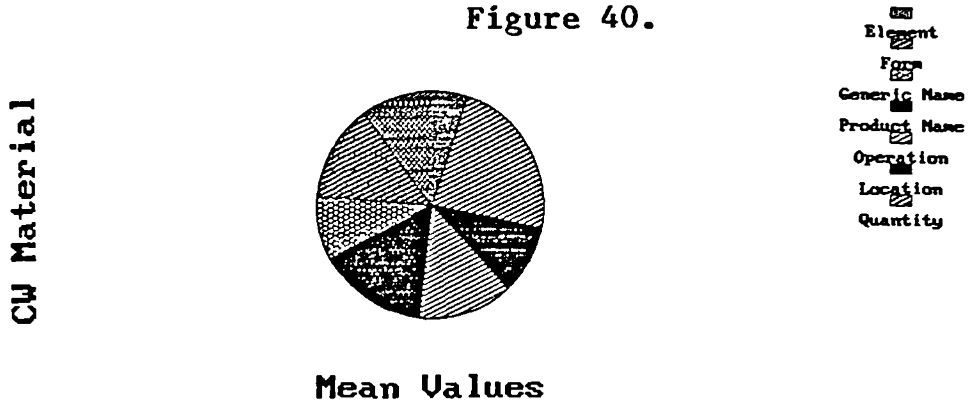
Figure 39.

Concrete Work - Material Attributes Analysis



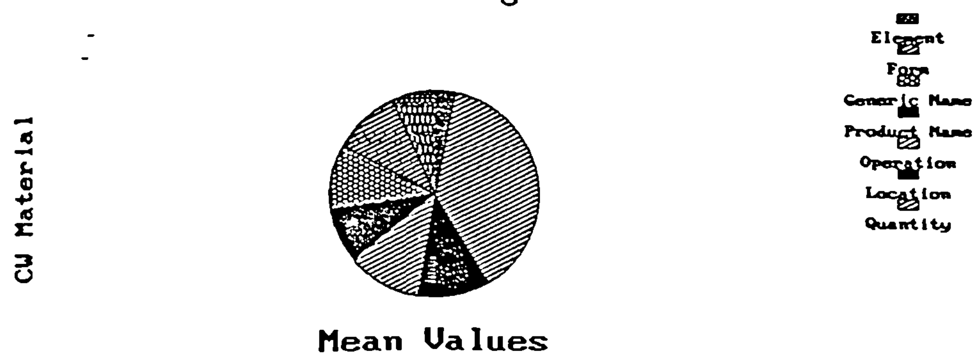

Undergraduate Responses

Figure 40.




Contractors Estimators Responses

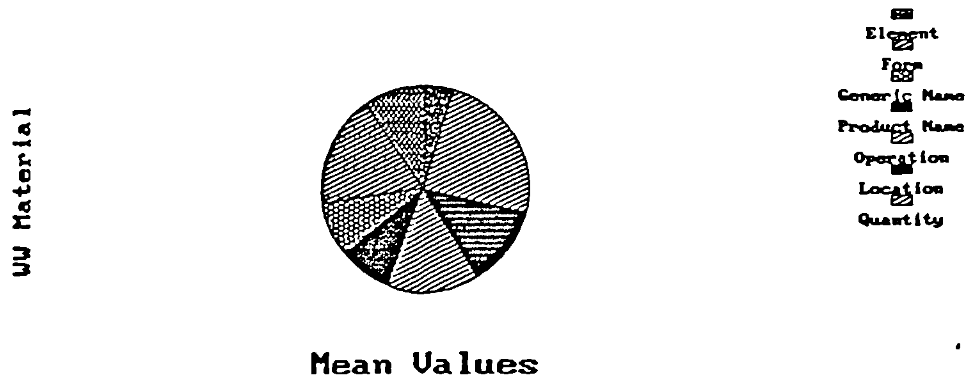
Figure 41.




Quantity Surveyors Responses

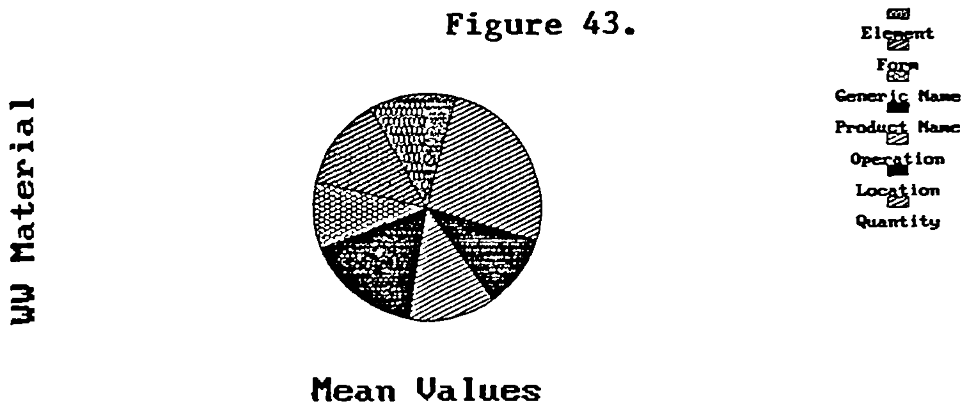
Figure 42.

WoodWork - Material Attributes Analysis



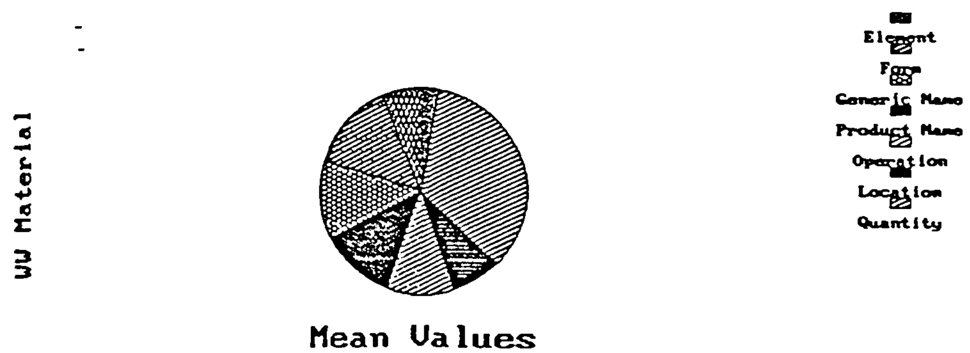

Undergraduate Responses

Figure 43.




Contractors Estimators Responses

Figure 44.




Quantity Surveyors Responses

Figure 45.

### B.5.3 Attribute Analysis - Labour Facet

As in the Material facet above it is the Quantity attribute which is dominant within the labour facet. This is particularly so among the sample of Quantity Surveyors where the value of this attribute ranges from 31.25 to 32.56. This is followed by the Operation facet which is clearly placed as the second most important facet with values ranging from 17.47 to 18.63.

As in the previous analysis there is a closer correlation between the responses of the Undergraduates and the Estimators than with the Quantity Surveyors. In the case of the Undergraduates the Quantity attribute ranges in value from 21.36 to 23.94 and in the case of Estimators from 20.57 to 25.93.

It can also be seen that in comparing the importance of attributes to the facets of Labour and Materials, there is a distinct change in balance of importance. Within the labour facet there is an increased importance of the attributes of operation, location and element with a comparative decrease in importance of form, generic name and product name.

When an attempt is made to group attributes according to whether they be artefact or dynamic based the comparison becomes even more revealing. When quantity is excluded it is seen that the value attributed to the artefact based attributes (Form, Generic Name, Product Name) reduces considerably from material to labour for all work sections while the dynamic attributes increase under the same conditions. In the case of All Measured Work the artefact values (excluding quantity) are; Undergraduates, 36.82 to 20.00, Estimators, 41.00 to 29.57, Quantity Surveyors, 42.14 to 25.65. Similarly the dynamic values (Operation, Location and Element) are; Undergraduates, 35.81 to 57.12, Estimators, 33.86 to 48.15 and Quantity Surveyors, 27.02 to 43.16.

In comparing the aggregate values of the dynamic and artefact attributes of materials and labour where quantity of labour is considered as a dynamic attribute a reverse situation to that which pertains in material occurs. In the labour facet the dynamic aspects are considered to have importance amounting to a values between 74.2 and 67.5. These values are very similar to those which occur for the artefact based aspects of the material facet.

It can be seen that for all types of the work the estimators rate the quantity of labour factor lower than do the quantity surveyors. This was reflected in comments made by the estimator respondents to the investigator which noted that the inclusion of a quantity of labour attribute within the bill of quantities was not reasonable. This suggested that their preference was to have the information available to them which would allow them to quantify labour. Thus the attributes element, form, operation and location were important in Concrete Work.

**All Measured Work - Labour Attributes Analysis**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 18.79 | 17.36 | 11.89 |
| Form | 10.61 | 13.43 | 11.36 |
| Generic Name | 5.00 | 8.64 | 8.85 |
| Product Name | 4.39 | 7.50 | 5.44 |
| Operation | 21.36 | 18.43 | 18.40 |
| Location | 16.97 | 12.36 | 12.87 |
| Quantity | 22.58 | 20.57 | 31.25 |
| | **% Values** | | |

**Table 20.**

**Concrete Work - Labour Attributes Analysis**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 18.18 | 20.43 | 11.81 |
| Form | 12.45 | 12.00 | 10.93 |
| Generic Name | 5.24 | 6.43 | 6.48 |
| Product Name | 3.52 | 5.43 | 5.17 |
| Operation | 21.21 | 19.50 | 18.63 |
| Location | 17.73 | 16.64 | 14.85 |
| Quantity | 21.36 | 22.00 | 31.45 |
| | **% Values** | | |

**Table 21.**

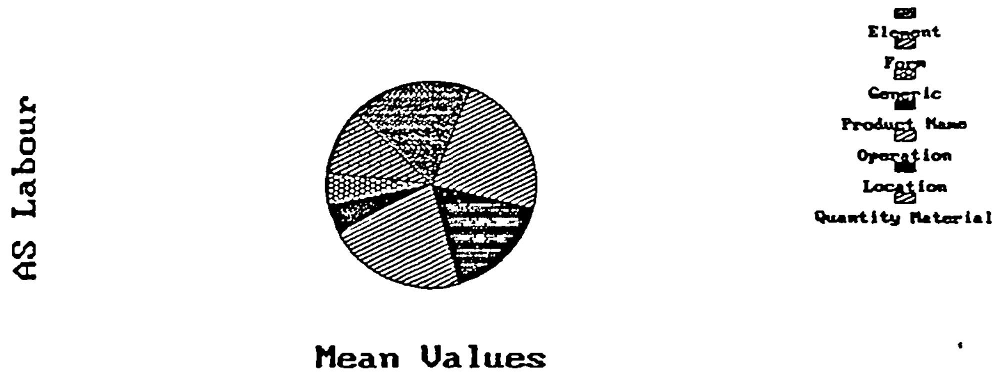
**WoodWork - Labour Attributes Analysis**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 18.18 | 14.71 | 11.04 |
| Form | 14.36 | 12.00 | 12.72 |
| Generic Name | 4.53 | 8.57 | 8.43 |
| Product Name | 5.33 | 7.71 | 6.09 |
| Operation | 18.64 | 15.57 | 17.47 |
| Location | 14.70 | 15.21 | 11.69 |
| Quantity | 23.94 | 25.93 | 32.56 |
| | **% Values** | | |

**Table 22.**

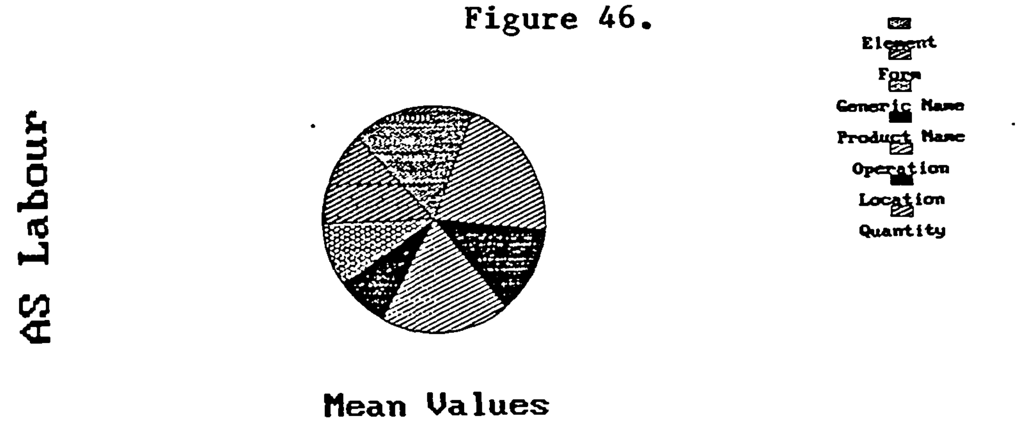
U/G is Undergraduate Responses
C/E is Contractors Estimators Responses
Q/S is Quantity Surveyors Responses

All Measured Work - Labour Attributes Analysis



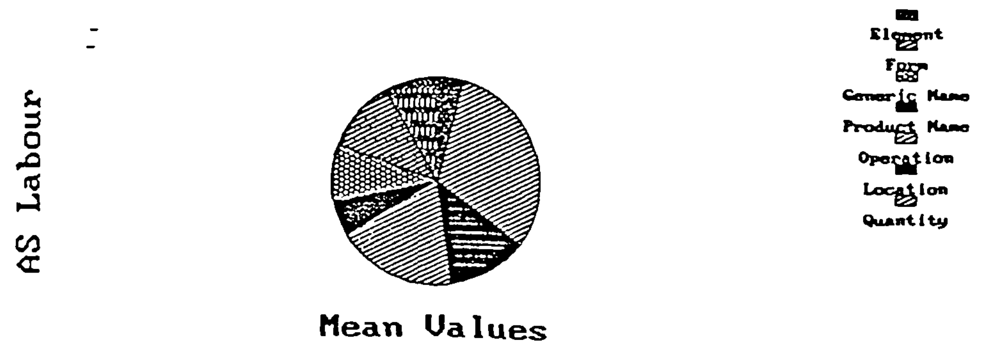

Undergraduate Responses

Figure 46.




Contractors Estimators Responses

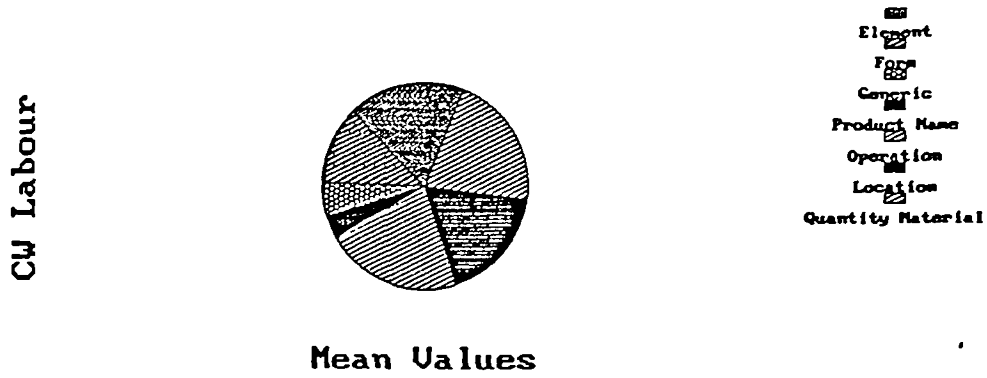
Figure 47.




Quantity Surveyors Responses

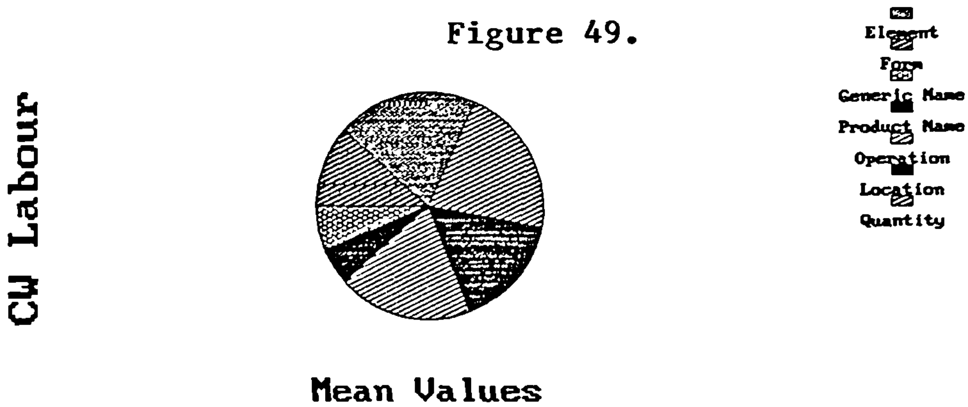
Figure 48.

Concrete Work - Labour Attributes Analysis



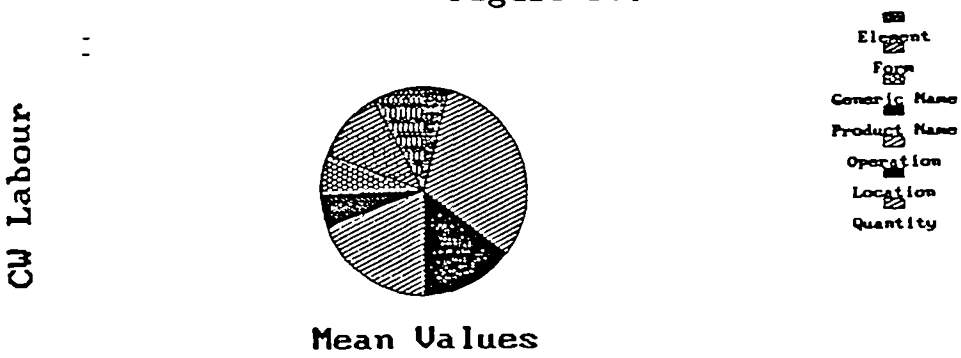

Undergraduate Responses

Figure 49.




Contractors Estimators Responses

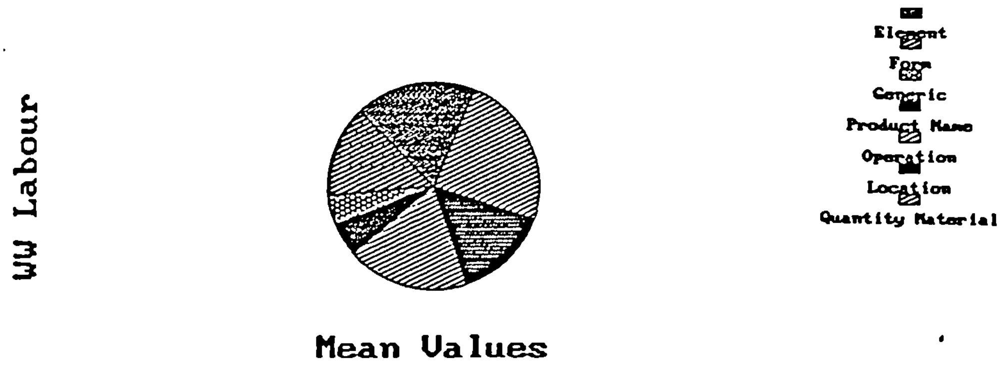
Figure 50.




Quantity Surveyors Responses

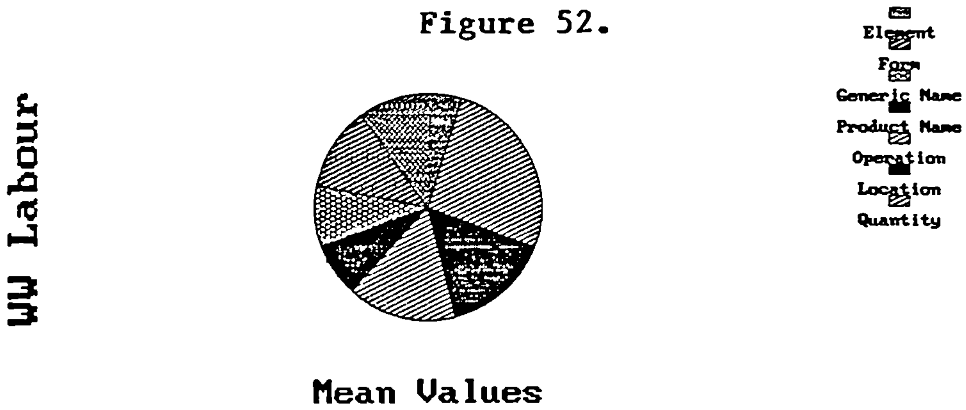
Figure 51.

WoodWork - Labour Attributes Analysis



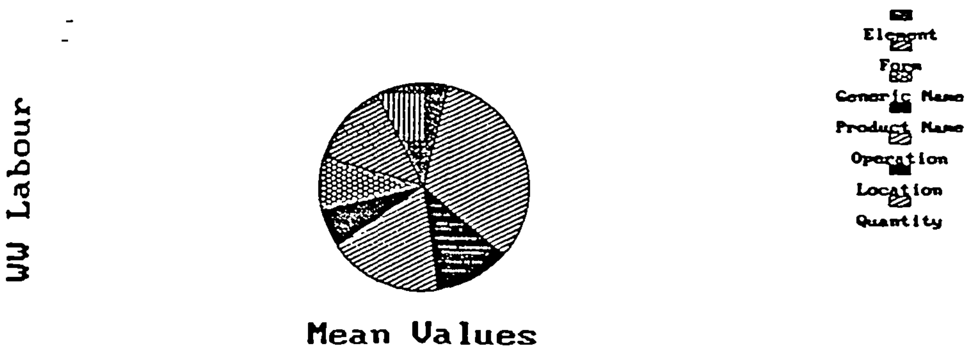

Undergraduate Responses

Figure 52.




Contractors Estimators Responses

Figure 53.



Quantity Surveyors Responses

Figure 54.

### B.5.4 Attribute Analysis - Plant Facet

Moving on to consider the Plant facet it can be seen in table 25 that the results produced are similar to those of the labour facet though there is a relative increase in the values of the location and element attributes. Overall there is a heavy weighting toward the dynamic attributes once again with aggregated values ranging from 77.4 to 70.9.

As in the Labour Facet investigation estimators expressed doubt as to the validity of including a quantity of plant attribute and as a consequence rated this attribute less than did the quantity surveyors. Once again, quantity surveyors rated quantity as the most important attribute in all cases.

All Measured Work - Plant Attributes Analysis

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 16.36 | 18.43 | 14.71 |
| Form | 10.76 | 12.21 | 9.63 |
| Generic Name | 6.21 | 7.00 | 7.31 |
| Product Name | 3.79 | 6.07 | 5.21 |
| Operation | 20.15 | 16.64 | 17.96 |
| Location | 23.79 | 16.64 | 17.11 |
| Quantity | 18.94 | 22.71 | 28.04 |

% Values

Table 23.

Concrete Work - Plant Attributes Analysis

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 16.06 | 17.36 | 12.97 |
| Form | 11.67 | 10.93 | 9.96 |
| Generic Name | 5.82 | 6.29 | 7.32 |
| Product Name | 3.12 | 4.14 | 5.17 |
| Operation | 21.06 | 12.36 | 16.13 |
| Location | 21.67 | 15.21 | 18.25 |
| Quantity | 20.45 | 19.14 | 31.52 |

% Values

Table 24.

WoodWork - Plant Attributes Analysis

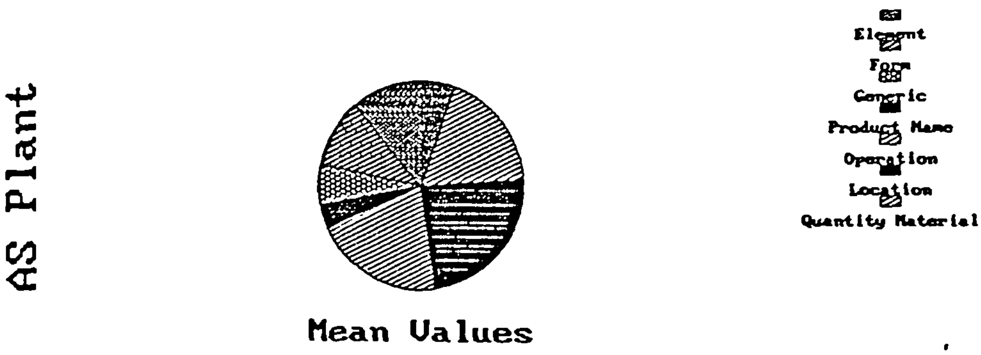
| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 14.39 | 14.86 | 11.88 |
| Form | 13.33 | 8.43 | 11.24 |
| Generic Name | 6.88 | 5.93 | 7.23 |
| Product Name | 4.33 | 5.93 | 5.75 |
| Operation | 19.85 | 10.57 | 15.87 |
| Location | 18.33 | 13.43 | 14.76 |
| Quantity | 23.03 | 21.29 | 30.41 |

% Values

Table 25.

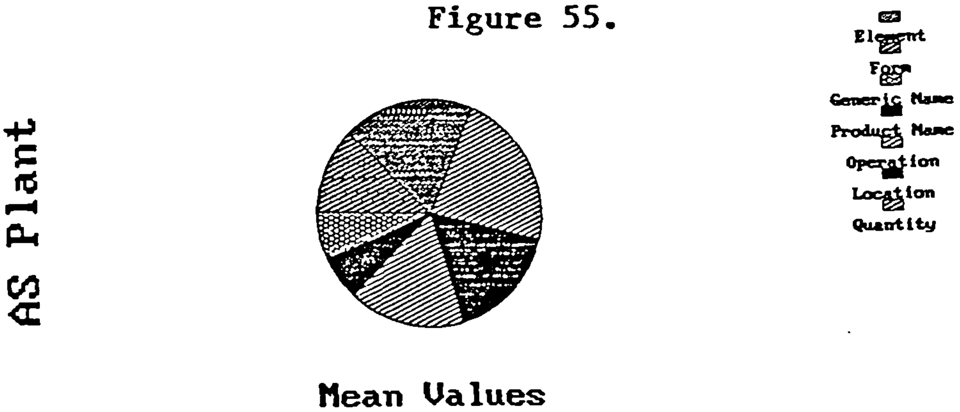
U/G is Undergraduate Responses
C/E is Contractors Estimators Responses
Q/S is Quantity Surveyors Responses

All Measured Work - Plant Attributes Analysis.



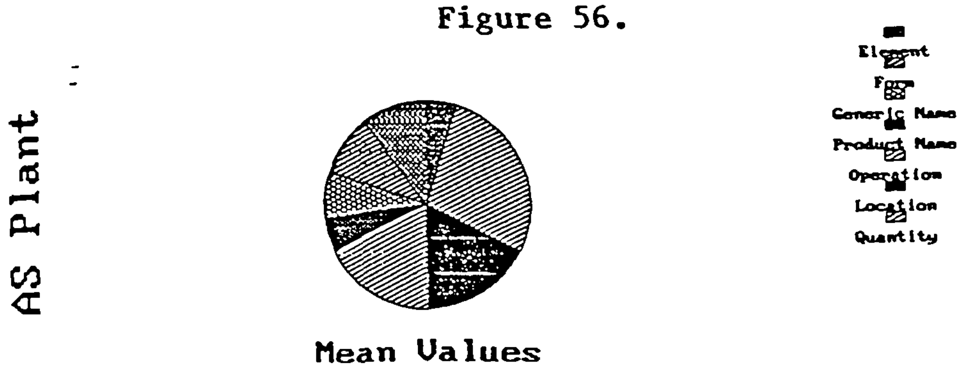

Undergraduate Responses

Figure 55.




Contractors Estimators Responses

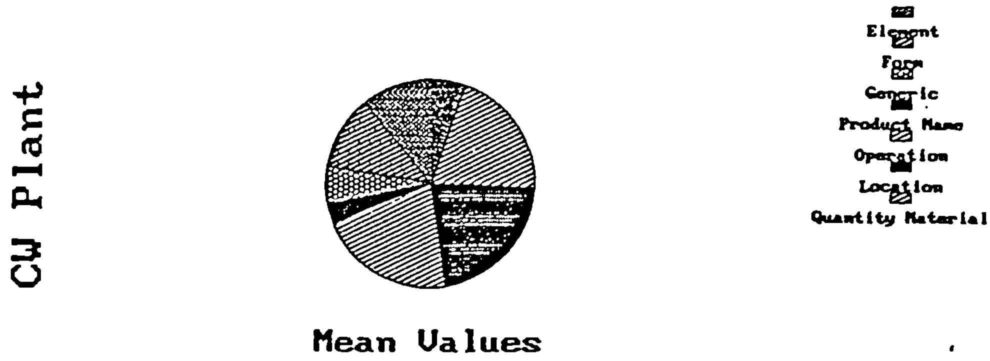
Figure 56.




Quantity Surveyors Responses

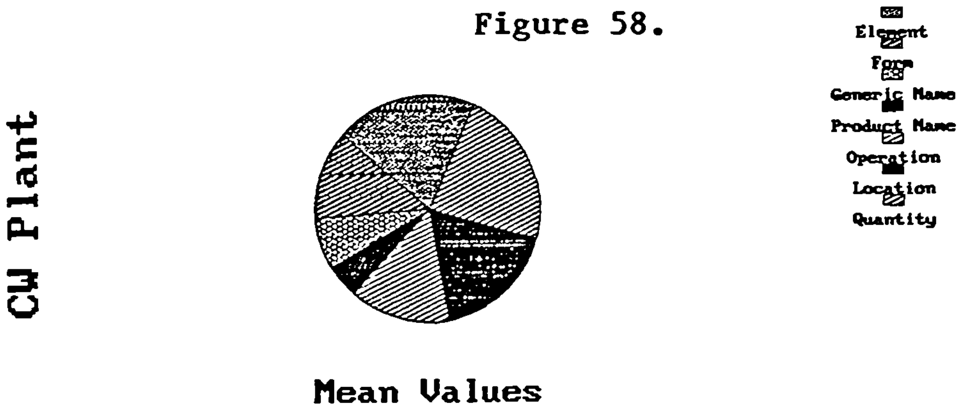
Figure 57.

Concrete Work - Plant Attributes Analysis



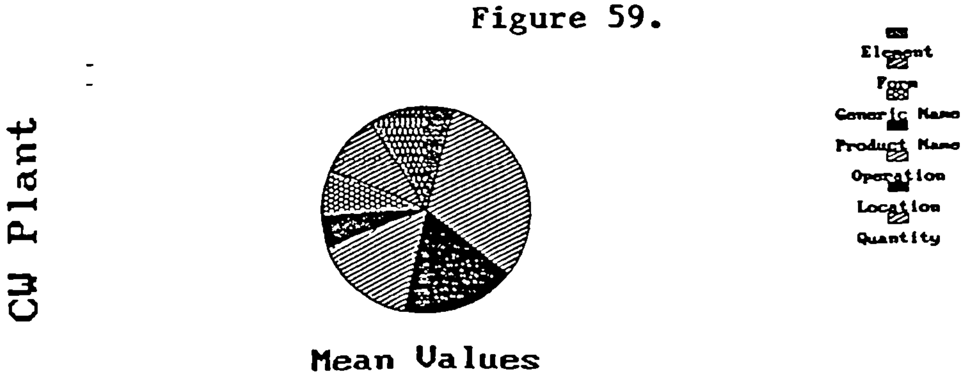

Undergraduate Responses

Figure 58.



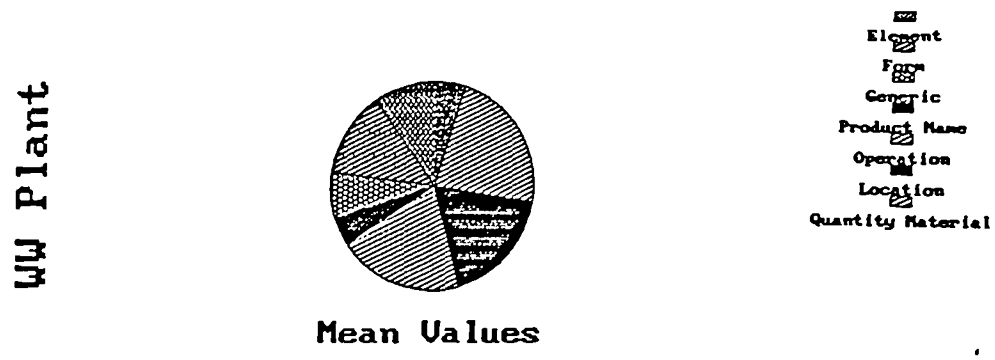

Contractors Estimators Responses

Figure 59.



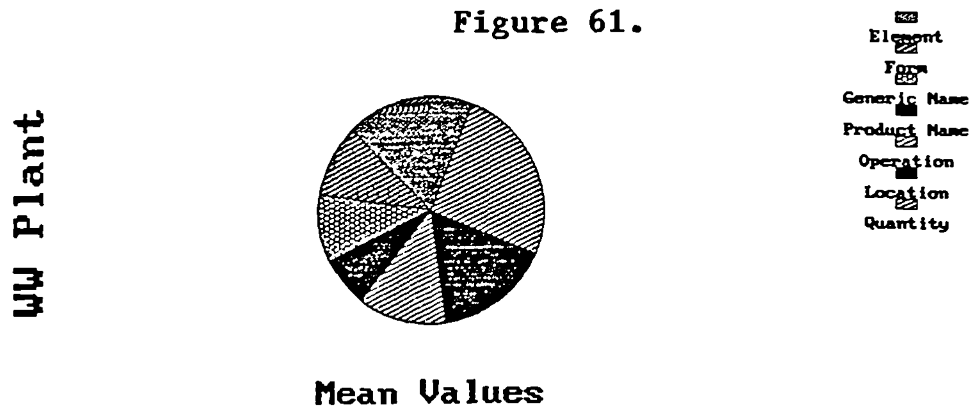

Quantity Surveyors Responses

Figure 60.



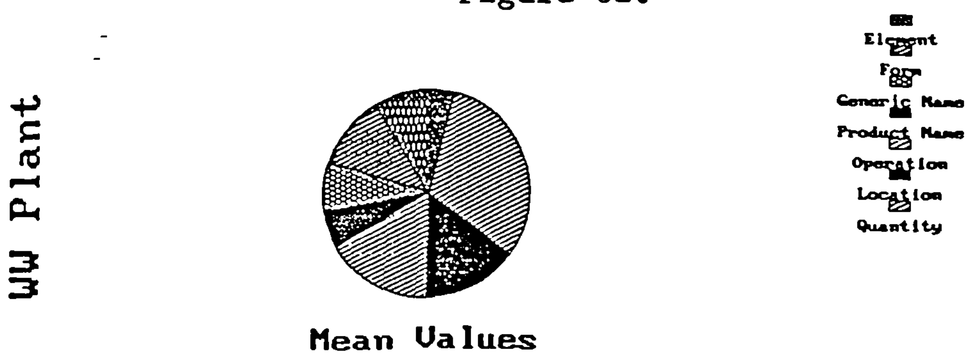

Undergraduate Responses

Figure 61.




Contractors Estimators Responses

Figure 62.




Quantity Surveyors Responses

Figure 63.

### B.5.5 Attribute Analysis - Site Overhead Facet

A review of the importance of attributes within the Overheads facet shows that Quantity is by far the most important, attracting a value greater than in any of the other facets, i.e. between 47.36 and 51.55 for Quantity Surveyors, 40.47 and 44.86 for Estimators and 28.94 and 39.70 for undergraduates.

Using the assumption that as overheads do not constitute part of the finished product their quantity forms part of the dynamic aspect of production, then values of between 68.8 and 84.27 are obtained for the dynamic attributes. This is greater than previously obtained.

Once again, and for the same reasons noted earlier the estimators rated the quantity attribute less important than did the quantity surveyors, but this attribute was rated more highly here by the estimators than in other facet investigations.

### B.5.6 Variability of Perceptions

As anticipated and noted in the investigation of Rees and Schultz (1967) the use of a ratio scale did not produce a normal distribution of responses. It is also clear that the interviewees were able to arrive at a more consistent response within there sample groups when considering the facets than when considering the attributes. This was reflected in the greater range of values obtained for the latter investigations.

**All Measured Work - Site Overhead Attributes**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 14.70 | 8.07 | 10.05 |
| Form | 9.24 | 10.57 | 7.19 |
| Generic Name | 4.55 | 7.36 | 4.47 |
| Product Name | 3.94 | 6.74 | 4.21 |
| Operation | 13.03 | 9.50 | 8.77 |
| Location | 16.36 | 9.50 | 12.63 |
| Quantity | 39.70 | 40.93 | 51.55 |

**% Values**

**Table 26.**

**Concrete Work - Site Overhead Attributes**

| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 14.70 | 9.86 | 10.48 |
| Form | 10.45 | 10.57 | 7.79 |
| Generic Name | 5.21 | 7.00 | 4.25 |
| Product Name | 4.79 | 4.86 | 4.03 |
| Operation | 15.45 | 7.36 | 10.79 |
| Location | 18.79 | 8.07 | 14.72 |
| Quantity | 30.45 | 44.86 | 48.28 |

**% Values**

**Table 27.**

**WoodWork - Site Overhead Attributes**

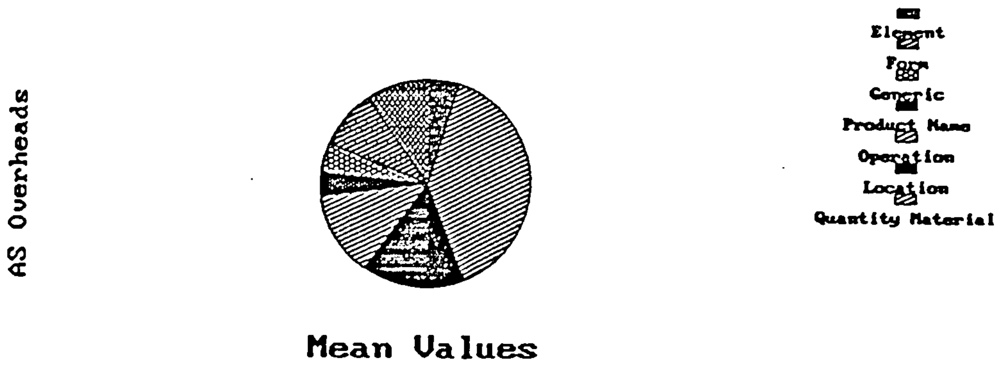
| | U/G | C/E | Q/S |
|---|---|---|---|
| Element | 16.21 | 9.14 | 8.33 |
| Form | 11.52 | 9.14 | 8.84 |
| Generic Name | 6.45 | 8.07 | 4.93 |
| Product Name | 5.82 | 5.93 | 5.15 |
| Operation | 14.39 | 12.00 | 10.13 |
| Location | 19.70 | 9.86 | 12.75 |
| Quantity | 28.94 | 40.57 | 47.36 |

**% Values**

**Table 28.**

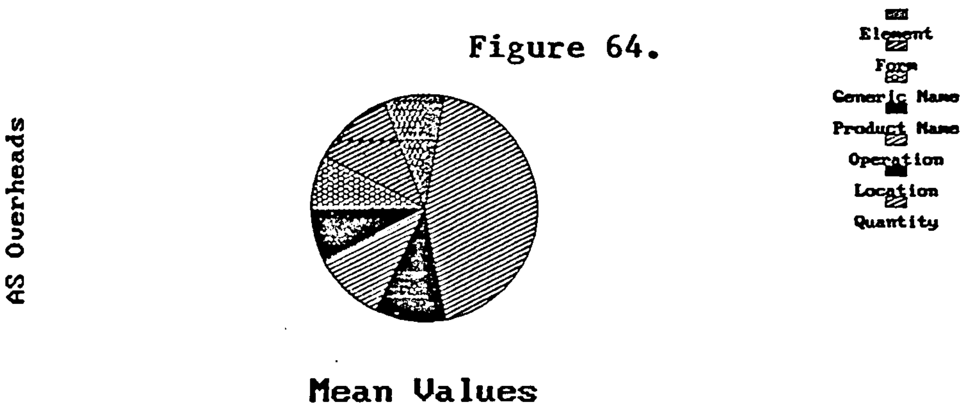
U/G is Undergraduate Responses
C/E is Contractors Estimators Responses
Q/S is Quantity Surveyors Responses

## All Measured Work - Site Overhead Attributes



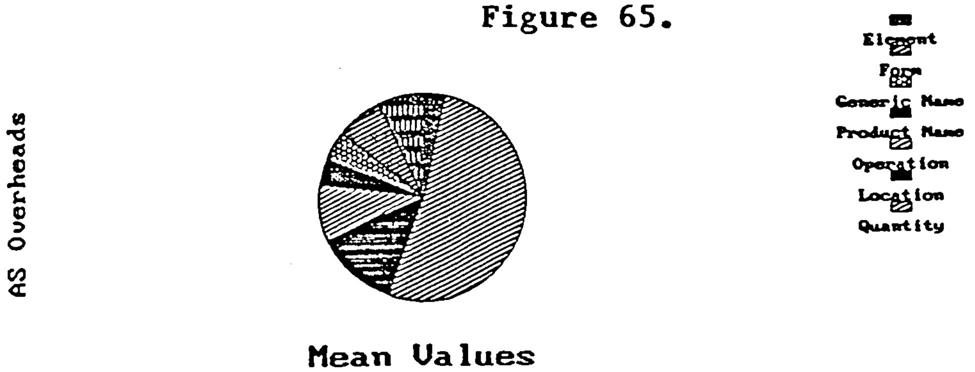

Undergraduate Responses

Figure 64.




Contractors Estimators Responses

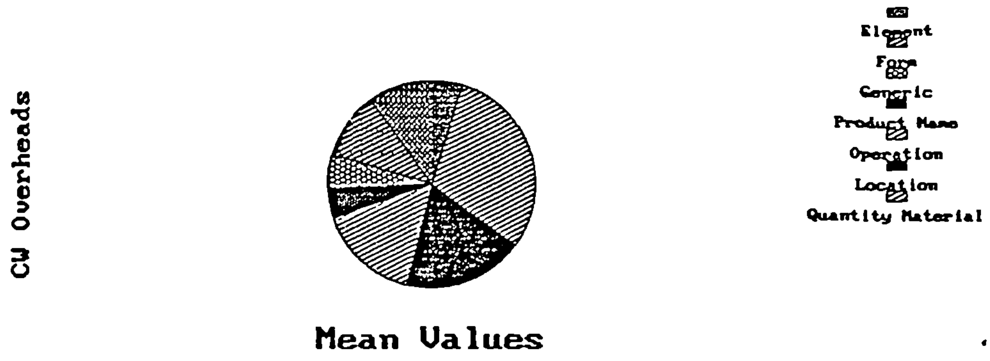
Figure 65.




Quantity Surveyors Responses

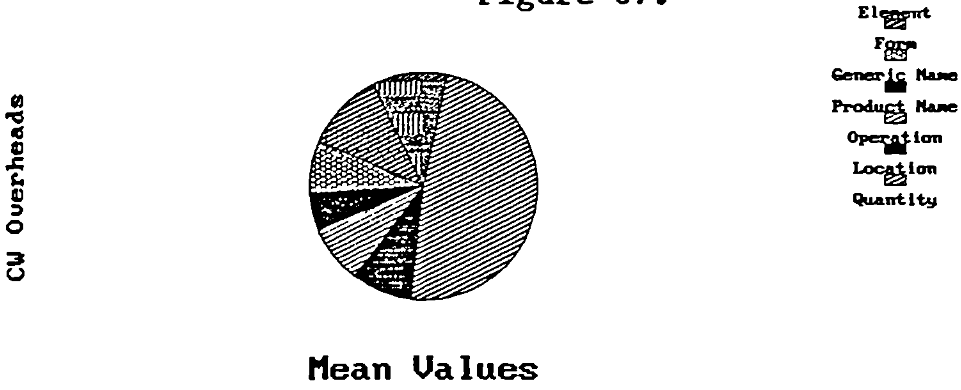
Figure 66.

Concrete Work - Site Overhead Attributes



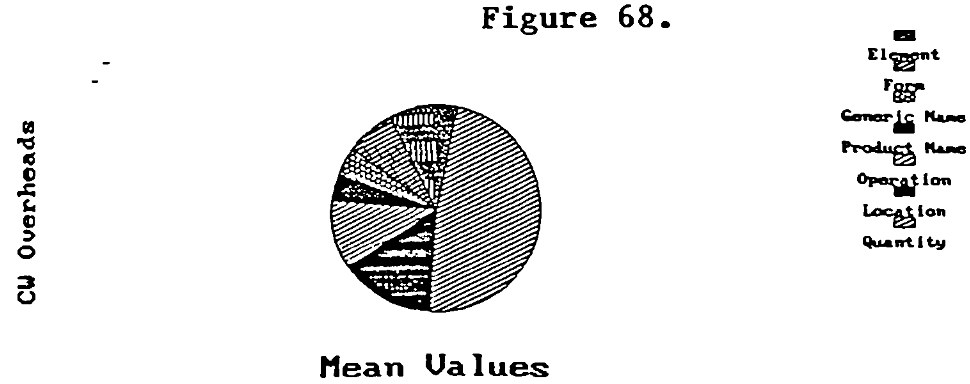

Undergraduate Responses

Figure 67.




Contractors Estimators Responses

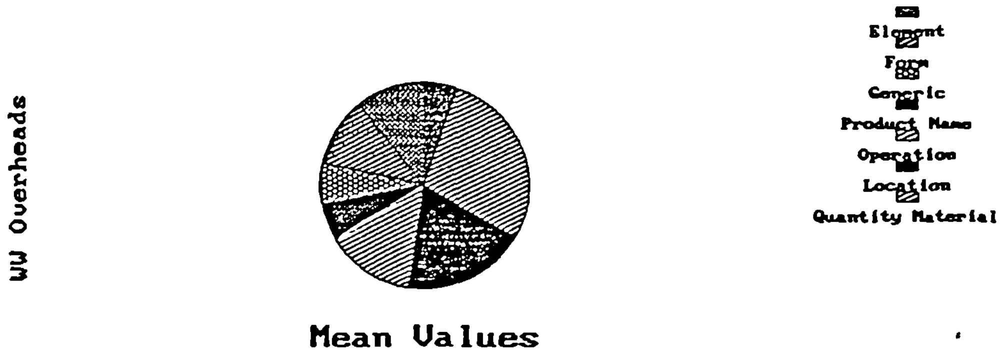
Figure 68.




Quantity Surveyors Responses

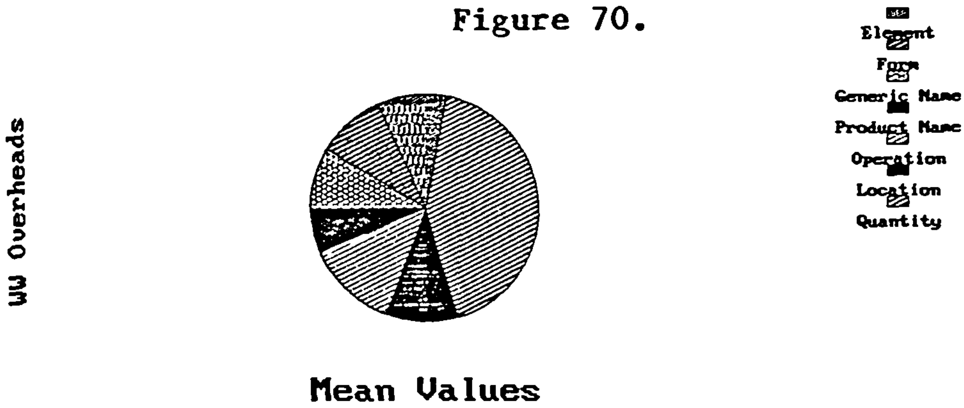
Figure 69.

WoodWork - Site Overhead Attributes



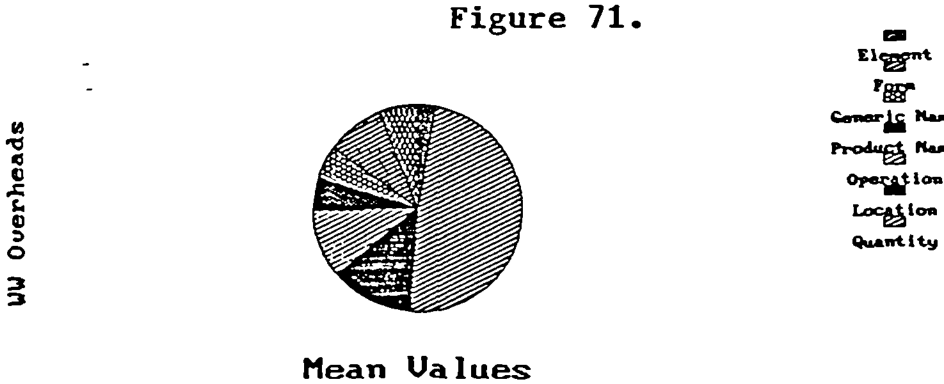

Undergraduate Responses

Figure 70.




Contractors Estimators Responses

Figure 71.




Quantity Surveyors Responses

Figure 72.

Mendenhall et al (1986) note that while the standard deviation is ideally suited to a normal distribution it is also an excellent description of many other types of data. Using the percentage standard deviation of the facet investigation for all work as the norm in each sample it was possible to show that in the case of the estimators and quantity surveyors the variability of responses increased when the specific work sections were considered. This did not occur with the undergraduates.

**Facet Variability**

| | U/G | C/E | Q/S |
|---|---|---|---|
| All Measured Work | 1.00 | 1.00 | 1.00 |
| Concrete Work | 0.89 | 1.11 | 1.17 |
| Wood Work | 0.95 | 1.49 | 1.13 |

**Table 29**

A similar analysis was carried out at the attribute level using the all measured work material attributes analysis as the norm for each sample. This showed that the variability of responses increased as the definition of information type was narrowed to the attribute level. It also demonstrated that most consistency of view was found in regard to the attributes of the materials facet, followed by labour, plant and overheads in which there was substantial variability among responses. The group which demonstrated least variability of response was the undergraduate group. This may well be a reflection of a greater

**Attribute Variability**

| | | U/G | C/E | Q/S |
|---|---|---|---|---|
| All Measured Work | Material | 1.00 | 1.00 | 1.00 |
| | Labour | 1.13 | 1.46 | 1.17 |
| | Plant | 1.06 | 1.46 | 1.28 |
| | Overheads | 1.36 | 1.75 | 1.50 |
| Concrete Work | Material | 1.16 | 1.20 | 1.22 |
| | Labour | 1.15 | 1.38 | 1.45 |
| | Plant | 1.22 | 1.81 | 1.59 |
| | Overheads | 1.29 | 1.93 | 1.62, |
| WoodWork | Material | 1.17 | 1.10 | 1.09 |
| | Labour | 1.27 | 1.36 | 1.29 |
| | Plant | 1.23 | 1.83 | 1.37 |
| | Overheads | 1.38 | 1.98 | 1.68 |

**Table 30**

coherence of (and more limited) knowledge base than is to be found among the other two groups. A view that is supported in the above investigation.

## APPENDIX C

## ESTIMATING INVESTIGATION

Respond to each of the following questions by identifying the five most important criteria.

Indicate these criteria by grading from '5' = most important through to '1' = least important.

1. What is your definition of an expert?

A. Experienced in a particular field _

B. Knowledgeable in a particular field _

C. Highly developed in skills applied to a particular field _

D. High level of intelligence _

E. Capable of applying theory to practice _

F. Has a good feel for work involved _

G. Can identify information required for the task _

H. Can interpret and manipulate information to complete task _

2. <u>What is your definition of an 'expert estimator'?</u>

A. Experienced and can evaluate markets effect on price _

B. Familiar with going prices and can store them in head _

C. Someone with a good feel for the job _

D. Has worked on estimates for 1 to 5 years _

E. Has worked on estimates for 6 to 10 years _

F. Has worked on estimates for more than 10 years _

G. Learns from previous jobs and performance levels _

H. Works logically and thoroughly _

I. Can see job as a whole at an early stage _

J. Can identify information required to complete estimate _

K. Can interpret and manipulate information to complete estimate _

3. <u>What skills does an expert estimator possess?</u>

A. Ability to apply experience _

B. Ability to identify information required _

C. Ability to interpret and manipulate information to complete estimate _

D. Can see job as whole at an early stage _

E. A feel for the market _

F. Thoroughness and accuracy _

G. Analytical brain and numeracy _

H. Intuition and flair _

I. Knowledge of labour and material prices _

J. Awareness of client requirements _

4. <u>What in your opinion are the most important factors to be considered in estimating construction prices?</u>

A. Construction quality and specification _

B. Type of building _

C. Client budget or cost limit _

D. Building size _

E. Building complexity _

F. The architect _

G. The site _

H. Market level _

I. Quality and quantity of information available _

J. Timing of scheme _

In regard to the following question please tick one answer only

5. <u>How well do you expect to do on this estimating task?</u>

A. + or - 5% _

B. + or - 10% _

C. + or - 15% _

D. + or - 20% _

E. + or - 25% _

F. + or - 30% _

G. greater than + or - 30% _

## APPENDIX D
## INFORMATION INVESTIGATION

If the following Project Description is provided to you, i.e.
0 Building type and tender date:
Please place in order of importance (1 to 16) the following further information which you may require to produce a cost estimate.

1 Client _

2 Floor Spec. _

3 Foundation Spec. _

4 Functional Unit _

5 Gross Floor Area _

6 Location _

7 No. of Tenderers _

8 PC Sums _

9 Provisional Sums _

10 Roof Spec. _

11 Services Spec. _

12 No. of Storeys _

13 Type of Contract _

14 VOP _

15 Walls Spec. _

16 Windows Spec. _

If the following Item Description is provided to you, building type, work section and tender date:

Please place in order of importance (1 to 7) the following further information which you may require to produce a cost estimate.

Element (e.g. roof, floor) _

Form of material (e.g. length, width) _

Generic name (e.g. wallboard) _

Product name (e.g. gyproc) _

Operation required (e.g. laying, placing) _

Location of material (e.g. 1st floor) _

Quantity of material _

## APPENDIX E

### PROJECT ESTIMATING

The exercise which you are about to complete is intended to identify the way in which information is used in cost estimating.

The exercise requires you to choose one piece of information and make a cost estimate of the tender figure for a sheltered housing project with a tender date of fourth quarter 1990. You may then choose a second piece of information and revise your estimate as you feel necessary. The exercise continues until all pieces of information have been used.

In order to help you, brief information has been compiled on 5 similar projects. Their costs have been updated.
If you have any queries during the exercise please raise them.

Project Description Number 1

| | | |
|---|---|---|
| 0 | Building type, value and date | Sheltered Housing<br>£708,810<br>February 1987 |
| 1 | Client | Housing Association |
| 2 | Floor Spec. | Precast Conc. + Screed |
| 3 | Foundation Spec. | Strip, reinforced |
| 4 | Functional Unit | 20 flats |
| 5 | Gross Floor Area | $1704m^2$ |
| 6 | Location | Tyne and Wear |
| 7 | No. of Tenderers | 6 |
| 8 | PC Sums | £101,178 |
| 9 | Provisional Sums | £20,525 |
| 10 | Roof Spec. | Timber pitched, tiled |
| 11 | Services Spec. | PC Sum for complete Htg<br>Water Inst. Lift |
| 12 | No. of Storeys | 3 |
| 13 | Type of Contract | JCT 1980 |
| 14 | VOP | Yes |
| 15 | Walls Spec. | Half brick facing<br>Cavity wall insluln.<br>100mm blockwork |
| 16 | Windows Spec. | Timber casement |

Project Description Number 2

| | | |
|---|---|---|
| 0 | Building type, value and date | Housing in flats<br>£303,852<br>March 1987 |
| 1 | Client | Housing Group |
| 2 | Floor Spec. | Chipboard on<br>Polystyrene on<br>PC Concrete |
| 3 | Foundation Spec. | Strip, reinforced |
| 4 | Functional Unit | 12 single person flats |
| 5 | Gross Floor Area | $557m^2$ |
| 6 | Location | Tyne and Wear |
| 7 | No. of Tenderers | 6 |
| 8 | PC Sums | £80,680 |
| 9 | Provisional Sums | £819 |
| 10 | Roof Spec. | Timber pitched, tiled |
| 11 | Services Spec. | Night storage heaters<br>Normal lighting + power |
| 12 | No. of Storeys | 3 |
| 13 | Type of Contract | JCT 1980 |
| 14 | VOP | Yes |
| 15 | Walls Spec. | Half brick facing<br>Cavity wall insluln.<br>100mm blockwork |
| 16 | Windows Spec. | High performance<br>Hardwood |

Project Description Number 3

| | | |
|---|---|---|
| 0 | Building type, value and date | Sheltered Housing<br>£783,787<br>October 1985 |
| 1 | Client | Housing Association |
| 2 | Floor Spec. | Precast Conc. |
| 3 | Foundation Spec. | Strip, reinforced |
| 4 | Functional Unit | 24 persons |
| 5 | Gross Floor Area | 1370m$^2$ |
| 6 | Location | Tyne and Wear |
| 7 | No. of Tenderers | 8 |
| 8 | PC Sums | £41,591 |
| 9 | Provisional Sums | £6,866 |
| 10 | Roof Spec. | Timber pitched, tiled |
| 11 | Services Spec. | Gas boiler LPHW Heating<br>Normal power + lighting<br>PC sum of £12000 Lift |
| 12 | No. of Storeys | 1 and 2 storeys |
| 13 | Type of Contract | JCT 1980 |
| 14 | VOP | NEDO |
| 15 | Walls Spec. | Half brick facing<br>Superblock inner skin |
| 16 | Windows Spec. | Softwood clear finish<br>Single glazing |



Project Description Number 4

| | | |
|---|---|---|
| 0 | Building type, value and date | Housing in flats<br>£640,705<br>May 1984 |
| 1 | Client | Housing Group |
| 2 | Floor Spec. | Precast Conc.+ screed |
| 3 | Foundation Spec. | Reinforced conc. raft |
| 4 | Functional Unit | 34 persons |
| 5 | Gross Floor Area | 1306m$^2$ |
| 6 | Location | Tyne and Wear |
| 7 | No. of Tenderers | 7 |
| 8 | PC Sums | £3,209 |
| 9 | Provisional Sums | £11,687 |
| 10 | Roof Spec. | Timber pitched<br>insitu infill areas<br>slates |
| 11 | Services Spec. | Night storage<br>Electric panel heaters<br>Electric fires<br>Normal power + lighting |
| 12 | No. of Storeys | 3 |
| 13 | Type of Contract | JCT 1980 |
| 14 | VOP | NEDO |
| 15 | Walls Spec. | Half brick facing<br>+ blockwork |
| 16 | Windows Spec. | Brazilian Mahogany<br>Reversible<br>Double glazed |

Project Description Number 5

| | | |
|---|---|---|
| 0 | Building type, value and date | Sheltered flats<br>£931,246<br>September 1983 |
| 1 | Client | Housing Association |
| 2 | Floor Spec. | Precast Conc. Beam<br>Thermoplastic tile<br>Sheet vinyl + carpet |
| 3 | Foundation Spec. | Strip, reinforced |
| 4 | Functional Unit | 38 persons |
| 5 | Gross Floor Area | $2003m^2$ |
| 6 | Location | Tyne and Wear |
| 7 | No. of Tenderers | 8 |
| 8 | PC Sums | £44,543 |
| 9 | Provisional Sums | £10,457 |
| 10 | Roof Spec. | Timber pitched, slates |
| 11 | Services Spec. | Gas fired boilers<br>Normal power + Lighting<br>Hydraulic lift |
| 12 | No. of Storeys | 3 |
| 13 | Type of Contract | JCT 1980 |
| 14 | VOP | NEDO |
| 15 | Walls Spec. | Half brick facing<br>Blockwork |
| 16 | Windows Spec. | Brazilian Mahogony |

## APPENDIX F

## FACET AND ATTRIBUTE QUESTIONNAIRE

INTRODUCTION

11 Name ...................... Please tick the appropriate answer

12 Age 21 - 30 yrs ____

31 - 40 yrs ____

41 - 50 yrs ____

51 - 60 yrs ____

over 60 yrs ____

13 Qualifications

Undergraduate ____

First Degree ____

Second Degree ____

ARICS/FRICS ____

None ____

Other ____

SECTION A

Please tick the appropriate answer

A1 Does your organisation prepare Bills of Quantities for the following areas of construction activity? ____

Building Construction ____

Civil Engineering ____

Both ____

A2 Is your organisation, ____

Local Authority? ____

Private Practice? ____

3 How many Chartered Quantity Surveyors are employed in the organisation?

1 - 5 ____

6 - 10 ____

11 - 20 ____

21 and above ____

A4 Is your position in your organisation equivalent to,

Senior Partner? ____

Partner? ____

Associate Partner? ____

Chief Quantity Surveyor? ____

Quantity Surveyor? ____

SECTION B

Please tick the appropriate answer

B1 Do you consider that in arriving at a realistic cost the measured item descriptions of SMM6 based Bill of quantities generally contain

More than adequate information? ____

Adequate information? ____

Less than adequate information? ____

B2 If you answered insufficient to the above question which aspects of information are considered to be deficient?

Material ____

Labour ____

Plant ____

Location ____

Assembly ____

Sequencing of Work ____

Construction Method ____

B3 Do you consider that the item descriptions to be found in SMM6 based bills of quantities are,

Difficult to understand? ____

Easy to understand? ____

Don't know ____

B4 In representing the work in a project do you consider that, in general bills of quantities based on the Standard Method of Measurement 6th Edition are a

True representation? ____

Almost true representation? ____

Untrue representation? _____

Don't know _____

B5 In costing items to be found in bills of quantities based on the Standard Method of Measurement 6th Edition, do you consider that you arrive at

True costs? _____

Almost true costs? _____

Untrue costs? _____

Don't know _____

SECTION D  All Measured Work

The following questions relate to all measured items sections of a bill of quantities.

The questions are a small part of a research project which aims to assess the perceived information requirements of a bill of quantities and the inherent information content and quality.

D1 Please divide 100 points among the following type of information which may be found in a bill of quantities, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

1.1 Description of material required ____

1.2 Description of plant required ____

1.3 Description of labour required ____

1.4 Description of site overheads required ____

| | | |
|---|---|---|
| D3 | <u>With regard to materials</u>, Please divide 100 points among the following types of information <u>which may be found in a bill of quantities</u>, to reflect your view of the relative importance of each characteristic to the contractor's estimating process. | <u>All Measured Work</u> |
| 3.1 | Element into which material is to be placed (eg roof, floor) | ____ |
| 3.2 | Form of material (eg length, width) | ____ |
| 3.3 | Generic name (eg wallboard) | ____ |
| 3.4 | Product name (eg gyproc) | ____ |
| 3.5 | Operation required (eg laying, placing) | ____ |
| 3.6 | Location of material (eg 1st floor) | ____ |
| 3.7 | Quantity of material | ____ |

| | | |
|---|---|---|
| D5 | With regard to labour, Please divide 100 points among the following types of information which may be found in a bill of quantities, to reflect your view of the relative importance of each characteristic to the contractor's estimating process. | All Measured Work |
| 5.1 | Element on which labour is to perform (eg roof floor) | ____ |
| 5.2 | Form of material (eg length, width) | ____ |
| 5.3 | Generic name (eg wallboard) | ____ |
| 5.4 | Product name (eg gyproc) | ____ |
| 5.5 | Operation required (eg laying, placing) | ____ |
| 5.6 | Location of operation (eg 1st floor) | |
| 5.7 | Quantity of labour | ____ |

D7 <u>With regard to plant</u>, Please divide 100 points among the following types of information <u>which may be found in a bill of quantities</u>, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

<u>All Measured Work</u>

| | | |
|---|---|---|
| 7.1 | Element on which plant is to perform (eg roof, floor) | ____ |
| 7.2 | Form of material (eg length, width) | ____ |
| 7.3 | Generic name (eg wallboard) | ____ |
| 7.4 | Product name (eg gyproc) | ____ |
| 7.5 | Operation required (eg laying, placing) | ____ |
| 7.6 | Location of operation (eg 1st floor) | ____ |
| 7.7 | Quantity of plant | ____ |

| | | |
|---|---|---|
| D9 | With regard to site overheads, please divide 100 points among the following types of information which may be found in a bill of quantities, to reflect your view of the relative importance of each characteristic to the contractor's estimating process. | All Measured Work |
| 9.1 | Element on which overhead is incurred (eg roof, floor) | _____ |
| 9.2 | Form of material to which overhead relates (eg length, width) | _____ |
| 9.3 | Generic name of material (eg wallboard) | _____ |
| 9.4 | Product name (eg gyproc) | _____ |
| 9 .5 | Operation required (eg laying, placing) | _____ |
| 9.6 | Location of overhead (eg 1st floor) | _____ |
| 9.7 | Quantity of overhead (eg Site accommodation for 6 months) | _____ |

SECTION E

Concrete Work Section

The following questions relate to Concrete Work section of a bill of quantities.

The questions are a small part of a research project which aims to assess the perceived information requirements of a bill of quantities and the inherent information content and quality.

E1 Please divide 100 points among the following type of information which may be found in a bill of quantities, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

1.1 Description of material required ____

1.2 Description of plant required ____

1.3 Description of labour required ____

1.4 Description of site overheads required ____

E3 <u>With regard to materials</u>, please divide 100 points among the following types of information <u>which may be found in a bill of quantities</u>, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

<u>Concrete Work Section</u>

3.1 Element into which material is to be placed (eg roof, floor) ____

3.2 Form of material (eg length, width) ____

3.3 Generic name (eg wallboard) ____

3.4 Product name (eg gyproc) ____

3.5 Operation required (eg laying, placing) ____

3.6 Location of material (eg 1st floor) ____

3.7 Quantity of material ____

E5 With regard to labour, please divide 100 points among the following types of information which may be found in a bill of quantities, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

Concrete Work Section

| | | |
|---|---|---|
| 5.1 | Element on which labour is to perform (eg roof, floor) | ____ |
| 5.2 | Form of material (eg length, width) | ____ |
| 5.3 | Generic name of material (eg wallboard) | ____ |
| 5.4 | Product name (eg gyproc) | ____ |
| 5.5 | Operation required (eg laying, placing) | ____ |
| 5.6 | Location of operation (eg 1st floor) | ____ |
| 5.7 | Quantity of labour | ____ |

E7 With regard to plant, please divide 100 points among the following types of information which may be found in a bill of quantities, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

Concrete Work Section

| | | |
|---|---|---|
| 7.1 | Element on which plant is to perform (eg roof, floor) | ____ |
| 7.2 | Form of material (eg length, width) | ____ |
| 7.3 | Generic name of material (eg wallboard) | ____ |
| 7.4 | Product name (eg gyproc) | ____ |
| 7.5 | Operation required (eg laying, placing) | ____ |
| 7.6 | Location of operation (eg 1st floor) | ____ |
| 7.7 | Quantity of plant | ____ |

E9 With regard to site overheads, please divide 100 points among the following types of information which may be found in a bill of quantities, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

Concrete Work Section

9.1 Element on which overhead is incurred (eg roof, floor) ____

9.2 Form of material to which overhead relates (eg length, width) ____

9.3 Generic name (eg wallboard) ____

9.4 Product name (eg gyproc) ____

9 .5 Operation required (eg laying, placing) ____

9.6 Location of overhead (eg 1st floor) ____

9.7 Quantity of overhead (eg Site accommodation for 6 months) ____

SECTION F

Woodwork Section

The following questions relate to all measured items of the Woodwork Section of a bill of quantities.

The questions are a small part of a research project which aims to assess the perceived information requirements of a bill of quantities and the inherent information content and quality.

F1 Please divide 100 points among the following type of information which may be found in a bill of quantities, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

1.1 Description of material required ____

1.2 Description of plant required ____

1.3 Description of labour required ____

1.4 Description of site overheads required ____

| | | |
|---|---|---|
| F3 | <u>With regard to materials,</u> please divide 100 points among the following types of information <u>which may be found in a bill of quantities</u>, to reflect your view of the relative importance of each characteristic to the contractor's estimating process. | <u>Woodwork Section</u> |
| 3.1 | Element into which material is to be placed (eg roof, floor) | _____ |
| 3.2 | Form of material (eg length, width) | _____ |
| 3.3 | Generic name (eg wallboard) | _____ |
| 3.4 | Product name (eg gyproc) | _____ |
| 3.5 | Operation required (eg laying, placing) | _____ |
| 3.6 | Location of material (eg 1st floor) | _____ |
| 3.7 | Quantity of material | _____ |

| | | |
|---|---|---|
| F5 | <u>With regard to labour,</u> please divide 100 points among the following types of information <u>which may be found in a bill of quantities</u>, to reflect your view of the relative importance of each characteristic to the contractor's estimating process. | <u>Woodwork Section</u> |
| 5.1 | Element on which labour is to perform (eg roof, floor) | ____ |
| 5.2 | Form of material (eg length, width) | ____ |
| 5.3 | Generic name (eg wallboard) | ____ |
| 5.4 | Product name (eg gyproc) | ____ |
| 5.5 | Operation required (eg laying, placing) | ____ |
| 5.6 | Location of operation (eg 1st floor) | ____ |
| 5.7 | Quantity of labour | ____ |

F7 <u>With regard to plant</u>, please divide 100 points among the following types of information <u>which may be found in a bill of quantities</u>, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

<u>WoodWork Section</u>

7.1 Element on which plant is to perform (eg roof, floor) ____

7.2 Form of material (eg length, width) ____

7.3 Generic name of material (eg wallboard) ____

7.4 Product name (eg gyproc) ____

7.5 Operation required (eg laying, placing) ____

7.6 Location of operation (eg 1st floor) ____

7.7 Quantity of plant

F9 With regard to site overheads, please divide 100 points among the following types of information which may be found in a bill of quantities, to reflect your view of the relative importance of each characteristic to the contractor's estimating process.

Woodwork Section

| | | |
|---|---|---|
| 9.1 | Element on which overhead is incurred (eg roof, floor) | ____ |
| 9.2 | Form of material to which overhead relates (eg length, width) | ____ |
| 9.3 | Generic name (eg wallboard) | ____ |
| 9.4 | Product name (eg gyproc) | ____ |
| 9 .5 | Operation required (eg laying, placing) | ____ |
| 9.6 | Location of overhead (eg 1st floor) | ____ |
| 9.7 | Quantity of overhead (eg Site accommodation for 6 months) | ____ |